

Pacific-IX Desktop Feasibility Study

Feasibility study into subsea cable
transmission and establishment of a
Pacific Islands Internet Exchange

Report prepared for



December 2019

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Declaration and Disclaimer

This Report has been prepared by Dr Paul Brooks of Layer 10 for the Internet Society, in support of the Asia-Pacific Information Superhighway initiative of UN-ESCAP.

In preparing this report, Layer 10 has relied primarily on information from publicly available sources, best practices documents and our domain expertise. While reasonable measures were taken to confirm, verify and validate these sources, we offer no warranty, express or implied, regarding any information referenced within.

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Executive Summary

Efficient network connections for carrying Internet traffic are essential for modern life and communications with neighbours and the broader globe.

Over the past decades, increasing numbers of nations are opening up their markets and allowing competition in the provision of telecommunications services, including Internet.

Internet exchange points (IXPs) are a vital part of the Internet ecosystem in that they enable two users in different networks to most efficiently exchange information in the broader Internet network system. Through the exchange of traffic at the closest IXP, service providers' efficiency is improved from reduced traffic and hence reduced congestion and costs of long-distance transmission links. The users and customers experience improved service levels through lower latency, improved responsiveness and often increased throughput to and from services. In this way, they are analogous to regional airport hubs—airlines exchange passengers between their flights in much the same way that networks exchange traffic across an IXP.

In the Pacific Islands region, there have been many improvements in foundation connectivity with several new subsea optical fibre cables coming online in the past 5 years, with more under construction and planned to be installed by 2022.

Many Pacific island nations however do not have an Internet Exchange Point (IXP) operating, causing inefficient Internet traffic flows as traffic between two provider networks often has to leave the country as it passes from customer to server and back again – often travelling all the way to the USA mainland and back. One or more IXPs is crucial in keeping 'local traffic local', which improves performance and reduces costs and congestion.

The development of national IXPs in the Pacific has been a topic of study and encouragement for several years within ESCAP, the Internet Society, as well as the Pacific Islands Telecommunications Association (PITA), Asia-Pacific Network Information Centre (APNIC), and the University of South Pacific (USP) IT group. Some nations, notably Fiji and PNG, are well advanced in operating a national IXP and a small number of others are in the process of establishing a national IXP, however the majority of Pacific Island nations do not have an active process for establishing a national IXP yet.

Some Pacific nations do not have multiple independent ISPs (and hence an IXP is not necessary) or may not have the scale and level of cross-ISP traffic to make significant benefit from a local IXP. However, when pooled together, the combined scale of many Pacific Island nations should provide significant benefits for all, if traffic between different island nations can be exchanged within the region, rather than having to be carried outside the region to a far-off IXP in the USA or Australia and back.

Executive Summary

As part of the development of the Asia-Pacific Information Superhighway (AP-IS) initiative¹, the United Nations Economic and Social Commission for Asia and the Pacific (UN-ESCAP) with the Internet Society (ISOC) initiated a feasibility study to establish whether a regional 'Pacific IXP' was feasible, to which multiple member nations could connect, and if it was thought to be feasible, where the physical infrastructure should be installed for best effect.

This study contributes to the implementation of UN-ESCAP's Asia-Pacific Information Superhighway initiative in the Pacific.

Conclusions

This study found that the collection of Pacific Island member states and associate member states are generally well connected by subsea cables, with many nations connected by at least one cable, and many particularly in the southern section connected (or soon to be connected) by two cables and in some cases more than two. While there are still some countries reliant on satellite connectivity and not connected by any subsea cable (notably Tuvalu, and Nauru), these are in the minority.

This study determined that the Pacific Island nations were split into two distinct zones – a **northern zone** surrounding the island of Guam, and a **southern zone** clustered loosely between Australia, New Zealand and Hawaii.

These two zones are significantly far apart, and no subsea cable connects the two zones together. Any traffic between a northern zone country and a southern zone country must pass through either Australia, or the USA either in Hawaii or the west coast of the USA mainland. As there are already very large, well-connected IXPs near the cable landings in Australia and USA, these IXPs will always be closer and provide more benefit to a Pacific nation than any IXP located within the other Pacific zone.

These characteristics make it infeasible for a single IXP to serve all nations, however each zone has a recommended IXP solution that should provide significant performance and efficiency benefits for each Pacific nation.

¹ <https://www.unescap.org/events/subregional-workshop-implementation-asia-pacific-informationssuperhighway-achieving>

Executive Summary

Northern Pacific Zone

The nations in the Northern Zone are generally all connected directly to Guam by cable, and the optimum location for a 'Northern Pacific Zone IXP' is for all ISPs to connect to one or both of the existing IXPs in Guam, to exchange traffic with each other and with the other networks present at those exchanges. These Guam IXPs either already have the major content networks connected, or are more likely to attract major content networks in future, than any separate IXP formed solely for the Pacific Island nations.

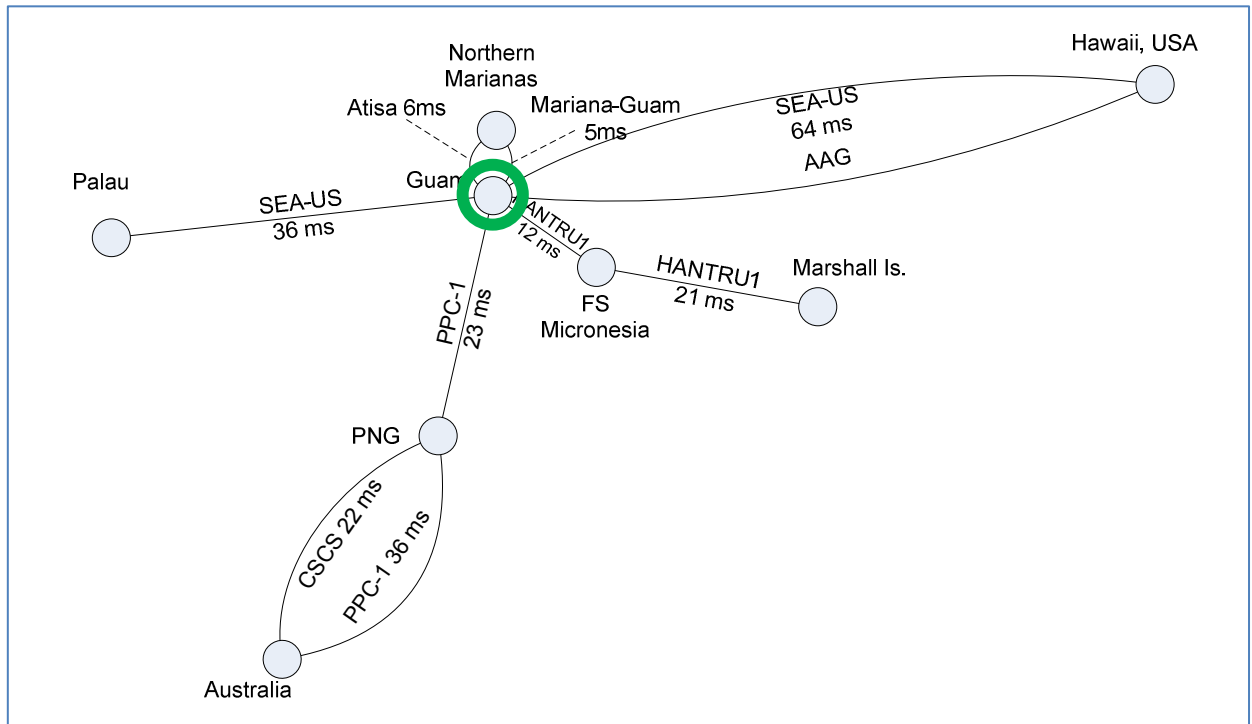


Figure 1 - Northern Pacific Zone cable latency map – recommend Guam IXPs

Southern Pacific Zone

This study recommends that the Southern Zone nations would be well served by a distributed Pacific IXP infrastructure, with nodes located in Fiji, Samoa, and New Zealand as shown below in Figure 2.

Each ISP in each nation would connect to the closest node of the IX (as well as to any in-country national IXP), and would then be able to establish peering interconnections to any other nation's ISP connected to the same node, or either of the other two nodes within the IX infrastructure. This minimises the costs of international capacity for those nations that are not hosting one of the nodes within their borders, and allows optimal sharing of resources and economies of scale in the solution for traffic sharing and keeping regional traffic regional.

Executive Summary

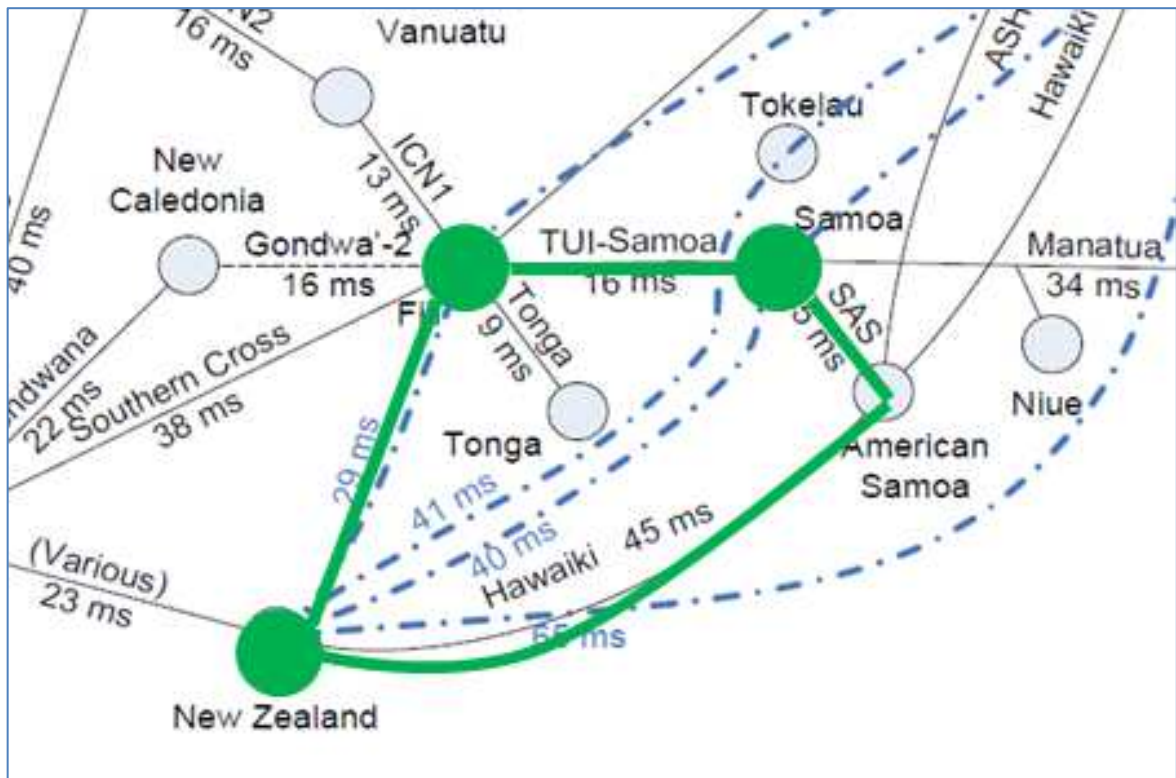


Figure 2 - Proposed distributed Southern Pacific IX 'ring'

This study established that such an arrangement is feasible and similar to other distributed IXPs from a technical engineering perspective. Further study is recommended to develop the cost models and operating models to ensure it can also be implemented when analysing the financial and organisational aspects of establishing this form of infrastructure.

Glossary of Terms

Glossary of Terms

Term	Definition
AP-IS	Asia-Pacific Information Superhighway – an initiative of ESCAP
APNIC	Asia-Pacific Network Information Centre – the Regional Internet Registry for the Asia Pacific, coordinating technical resources and providing information, training, and supporting services to assist the community in building and managing the Internet
CDN	Content Delivery Network – a distributed set of servers to which Internet content is sent, in order to be delivered from a point close to the user to improve response time, availability and scalability
DC	Datacentre- a secure building for locating IT equipment, generally with environmental controls, air-conditioning and humidity controls, and reliable backed-up power supplies
DWDM	Dense Wave-Division Multiplexing – a method used with optical fibre cables of encoding signals on many parallel frequencies of light, enabling a single pair of optical fibres to carry up to many Tbps of traffic
ESCAP	Economic and Social Commission for Asia and the Pacific, a body of the United Nations
IP	Internet Protocol – the fundamental protocol of all Internet communication. An Internet Standard defined by the Internet Engineering TaskForce. Usually combined with TCP and written TCP/IP
ISOC	The Internet Society – a global not-for-profit organisation promoting the open development, evolution and use of the Internet for the benefit of all people, with over 130 localised chapters across the globe
ISP	Internet Service Provider. A provider of Internet services to customers.
IX, IXP	Internet Exchange, Internet Exchange Point – a location where multiple network service providers and ISPs agree to interconnect their networks and exchange Internet traffic
ITU-T	International Telecommunications Union – Telecommunications Standardisation Sector is the global international standards body developing and ratifying telecommunications technology standards. (https://www.itu.int)
Kbps, Mbps, Gbps, Tbps	Kilobits, Megabits, Gigabits, Terabits per second – measures of data carrying capacity of a transmission link
PoP	Point-of-Presence – a physical point where a customer can connect to a network that spans many locations. Often also referred to as a ‘node’ of a distributed infrastructure.
RTT	Round Trip Time – the time for information to travel from the source to the destination, and then for an answer to return to the source location again. The forward path and return path might be different.
TCP	Transmission Control Protocol – an Internet Standard fundamental protocol for reliable data delivery over the Internet. Usually combined with IP and written TCP/IP.

Introduction

1. Introduction

Submarine cables built with optical fibres have revolutionised global long-distance telecommunications, providing enormous bulk capacity between nations and across oceans. Construction costs over decades have remained largely static on a per-kilometre basis, consisting primarily of the capital costs of the cable, plus the deployment costs of cable ships and their crews. The latent capacity of such cables has dramatically increased over the past decades due to improvements in the technology used on the shore landing stations to drive the signals along the fibres, and also improvements to the technology of the intermediate amplifiers that lie on the ocean floor, spaced approximately 100 km apart – using current state-of-the-art optical equipment, total capacity of 10 to 20 Terabits per second (Tbps) per pair of optical fibres is achievable over trans-oceanic distances, and more is possible over shorter distances.

The net result of these cost and performance dynamics is that the cost of a unit of capacity (say, a 10 Gbps optical channel) has decreased dramatically over the past two decades.

Once built and laid on the ocean floor, the submarine cable path and connectivity between nations is inflexible, and fixed for the life of the cable – typically 25 years or more.

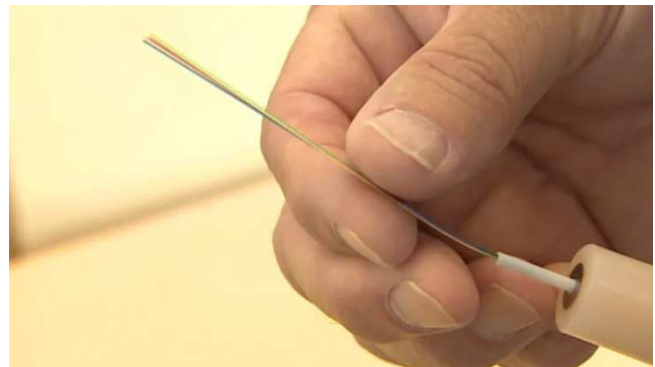


Figure 3 - Cable showing optical fibres

1.1. Impact of multiple ISPs

When a country develops a liberalised Internet service market, with multiple service providers, often the multiple network operators will want to keep their networks separated from each other for competitive reasons. Different network operators and service providers may be unable to negotiate acceptable terms and methods for interconnecting networks for many possible reasons, including an inability to agree on whether each party is a 'customer' or 'supplier' to the other, and hence whether or how much each party should pay the other.

These concerns often lead to a lack of local interconnection, and therefore traffic that needs to travel between customers of the two networks must travel outside the country and often over very long distances to a common connection point between one or more international upstream connectivity suppliers of the national service provider networks.

Introduction

In the absence of an agreed supplier-customer relationship, two or more independent service providers in a country might agree that they are 'peers' of relatively equal standing with each other, and agree to interconnect their networks and exchange their customers' traffic (but not their suppliers' traffic) for little or no costs paid from one to the other (or sometimes with equal contribution to the interconnection infrastructure costs) on the grounds that each network and their customers benefits equally by the peering interconnection..

This 'peering' relationship can occur bilaterally by agreement, however when there are more than two or three such networks it become more efficient and lower cost to formalise the arrangement at an IXP location and share the IX infrastructure costs amongst multiple participants.

1.2. Relationship to Asia-Pacific Information Superhighway Plan

This study applies to the Pacific Islands group of nations, and covers the following two items in the AP-IS Plan:

- Physical network design, development, management at regional level
- Ensuring efficient and effective Internet traffic and network management at regional, subregional and national levels

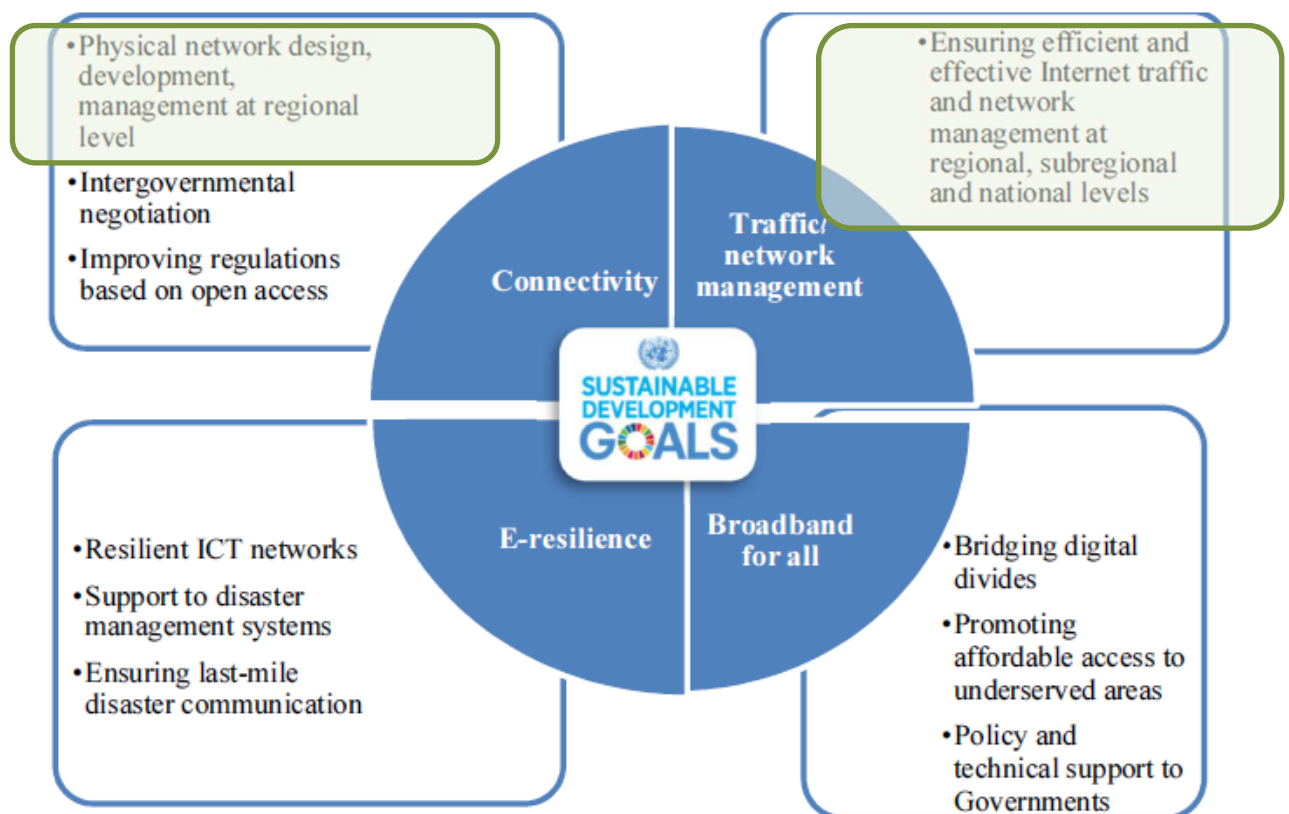


Figure 4 - Four Pillars of Asia-Pacific Information Superhighway

Introduction

1.3. Study Goals

The goals of this study described in this report are, for the Pacific Islands nations within the UN-ESCAP jurisdiction:

- review current Pacific Islands submarine cable inter-connectivity (i.e. which countries are linked directly by cable to each other)
- tabulate number of international gateways in the Pacific Islands and their international connection hub (i.e. where does the international link terminate for traffic exchange)
- where data is available, tabulate international transit capacity of each country
- based on data available, assess technical feasibility of establishing a regional Pacific IXP
- if a regional IXP is feasible, identify potential location(s)

This report was commissioned by the Internet Society through the Asia-Pacific Regional Bureau¹. The full scope of the study is included in Section 7 below.

1.4. Three layers of investigation

There are three distinct 'layers' under consideration to evaluate international connectivity within the Pacific Islands region:

- Underlying subsea cable infrastructure available to enable Pacific Island nations to interchange Internet traffic with each other directly the shortest practicable path;
- Which services and traffic sources users are attempting to access; and
- The current volumes of traffic, and forecast growth in traffic, accessing those services, and services hosted by other Pacific Island nations.

In this paper, the first point regarding underlying subsea cable infrastructure, is reported in Chapters 3 and 4 below, with an investigation into cable characteristics in latency and capacity. Additional insights in the architecture of subsea cables that impacts this analysis is provided in Chapter 5 below.

The second point, regarding services and traffic sources including websites, is investigated in Chapter 6 below, to arrive at a methodology that concentrates on the small number of major Internet content platforms and website accelerator platforms rather than on the thousands of potential websites and services users may be attempting to access.

The third point, regarding traffic volumes and forecasts of traffic growth to a proposed Pacific regional IXP, requires more focussed Internet traffic measurements and engagement with individual Internet Service Providers in each nation as part of estimating the aggregate capacity in detailed engineering of the recommended solution. This extended investigation is recommended as a follow-up study to this report.

¹ <https://www.internetsociety.org/regions/asia-pacific/>

Feasibility and Location of proposed Pacific IX

2. Feasibility and Location of proposed Pacific IX

2.1. UN-ESCAP Pacific Island Connectivity Overview

The UN-ESCAP Subregional Office for the Pacific² covers the Pacific Island nations of Fiji, Kiribati, Marshall Islands, Federated States of Micronesia (FSM), Nauru, Palau, Papua New Guinea, Samoa, Solomon Islands, Tonga, Tuvalu and Vanuatu. In addition, American Samoa, the Cook Islands, French Polynesia, Guam, New Caledonia, Niue and the Northern Mariana Islands are associate members.

When looking at the connectivity of these nations via undersea cables, it is evident they divide into two distinct regions – a northern zone, centred around the island of Guam, and a southern zone, clustered in an area between Australia, New Zealand and Hawaii.

These are illustrated below:

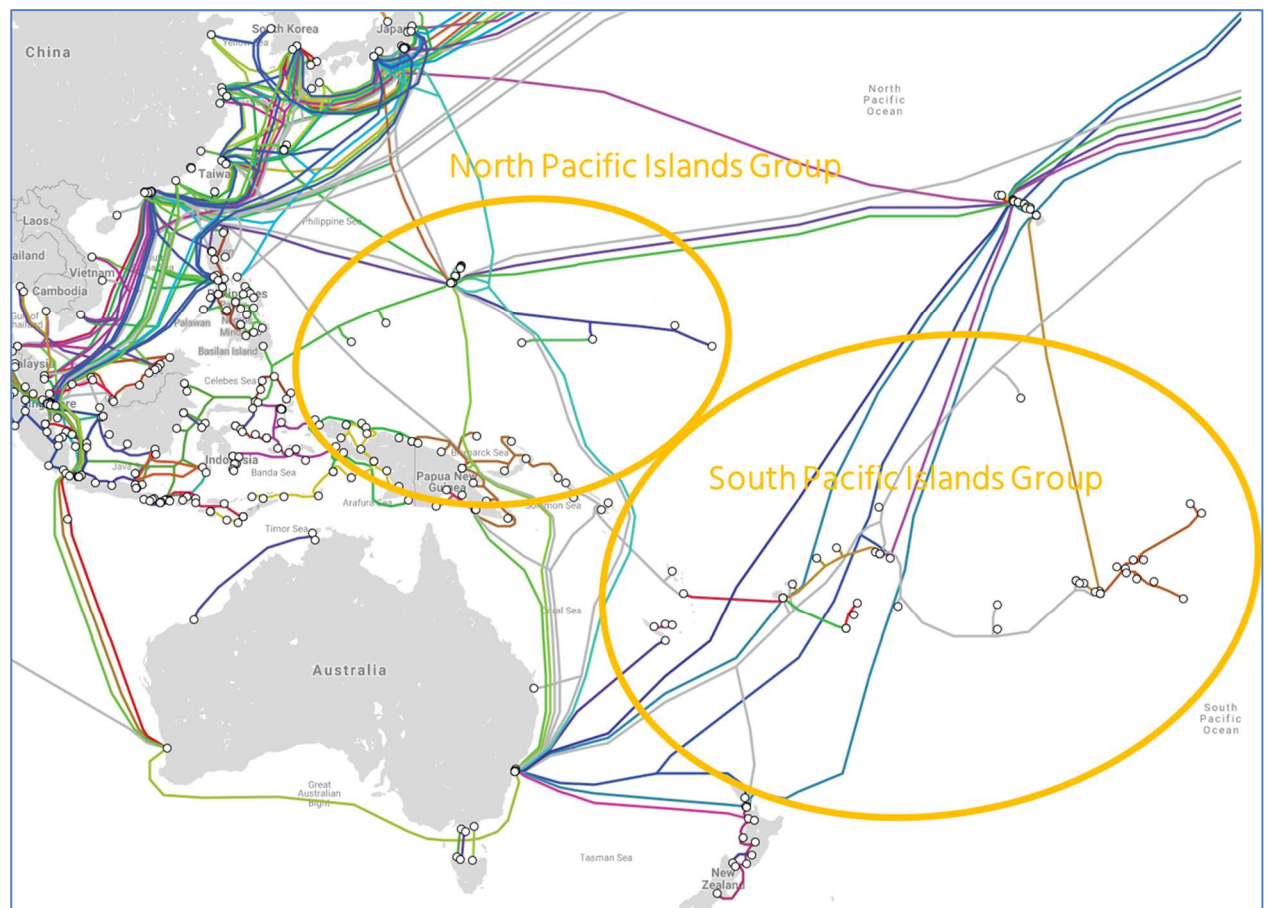


Figure 5 - Pacific Island nations and cables (source: Telegeography)

There are no cables that link the northern and southern zones directly.

² Subregional Office for the Pacific, <https://www.unescap.org/subregional-office/pacific>

Feasibility and Location of proposed Pacific IX

Three cables link Guam to Australia (AJC, JGA-2 under construction, and PPC-1 which also connects to Madang, PNG). Two other cables (AAG and SEA-US) link Guam to Hawaii.

While an operator could use these cables in combination with the cables from Hawaii to the southern Pacific islands to connect to Guam, the latency on this path is significantly higher (~ 66 ms Guam-Hawaii plus ~ 50 ms Hawaii – Fiji = ~ 116 ms) than the path to connect to other closer major IXPs, such as in Sydney, Auckland, or Hawaii itself, or even in the mainland USA, so there is little benefit to using such a long path to form Internet peering relationships.

It is clear from the cable routing that there is no one single location that forms a natural hub for the entire region, that would be a good place to locate an aggregated Pacific IX. With the natural grouping into a northern zone and a southern zone, each zone will have its own natural centre for location of an IX.

2.2. Northern Zone Pacific IX

Chapter 3 below surveys each of the Northern Zone countries and their cable connectivity.

It is clear that the US territory island of Guam forms a natural hub, with each nation connected directly by subsea optical fibre cable to Guam, and several high-capacity trans-pacific cables transiting through Guam between the USA and Asia.

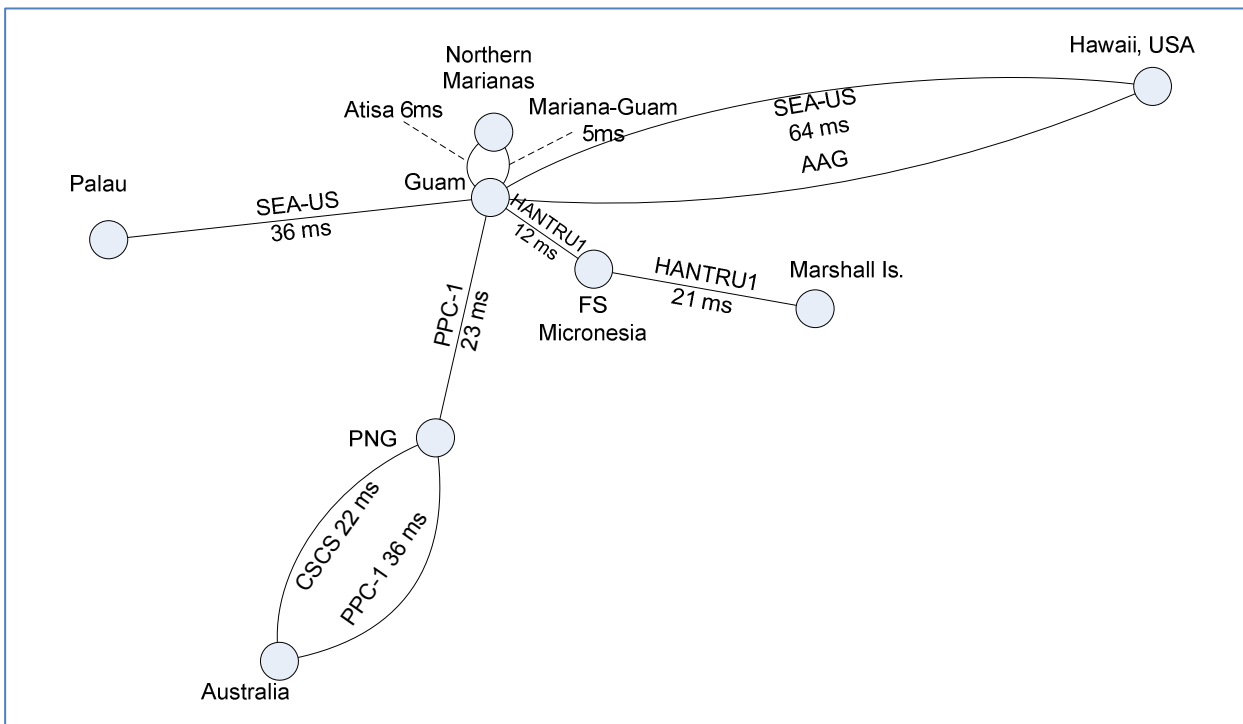


Figure 6 - Northern Pacific Zone cable latency map

Figure 6 is a diagram showing only the cables that connect to Pacific island nations, and is scaled by the round-trip-time latency measured in milliseconds directly connecting each nation.

Feasibility and Location of proposed Pacific IX

This diagram makes it clear that Guam forms a natural central location for a Pacific IX to serve these countries. As there are already at least three IXPs operating in Guam, these northern Pacific island nations should seek to establish connections into one or more of the existing IXPs, and there should establish peering sessions between themselves and with other networks in the area.

The two IXPs currently operating in Guam:

Guam Internet Exchange - GU-IX

URL: <http://www.gu-ix.net>

Operated by Guam Cablevision LLC

GU-IX is a layer-two Internet Exchange over Ethernet. All routers on the Ethernet are exchanging routing tables (or peering) with the route server set up by GU-IX using BGP4.

GU-IX is a settlement-free interconnection point

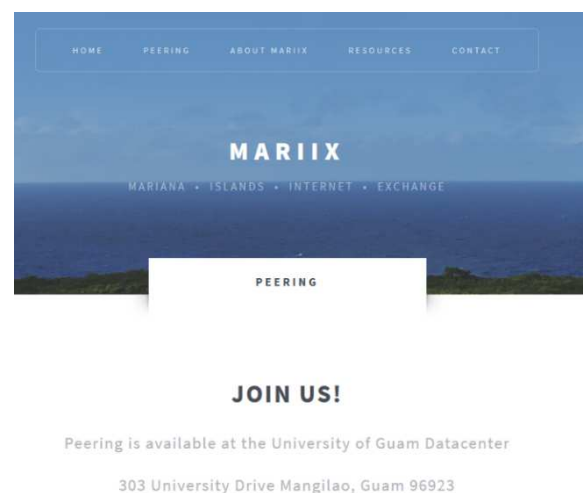
The main purpose of the GU-IX is for routing of intra-Guam traffic but it is acceptable if participants allow others to exchange traffic with their peer or downstream network(s) at other countries free of charge.



Mariana Islands Internet Exchange – MARIIX

URL: <https://mariix.net/about>

The Mariana Islands Internet Exchange, or MARIIX, is a project operated at and partially funded by the University of Guam's Office of Information Technology (OIT). The purpose of MARIIX is to allow local Internet Service Providers (ISPs) on Guam to inter-connect without sending traffic destined for each other's networks through international links. The MARIIX network will operate independently of all other networks, and will serve only as a means of connection among ISPs that choose to peer at MARIIX.



Feasibility and Location of proposed Pacific IX

2.3. Southern Zone Pacific IX Map

Chapter 4 below surveys each of the Southern Zone countries and their cable connectivity.

Unlike the northern zone, there is no clear natural hub that can be identified as an optimum location for an IXP.

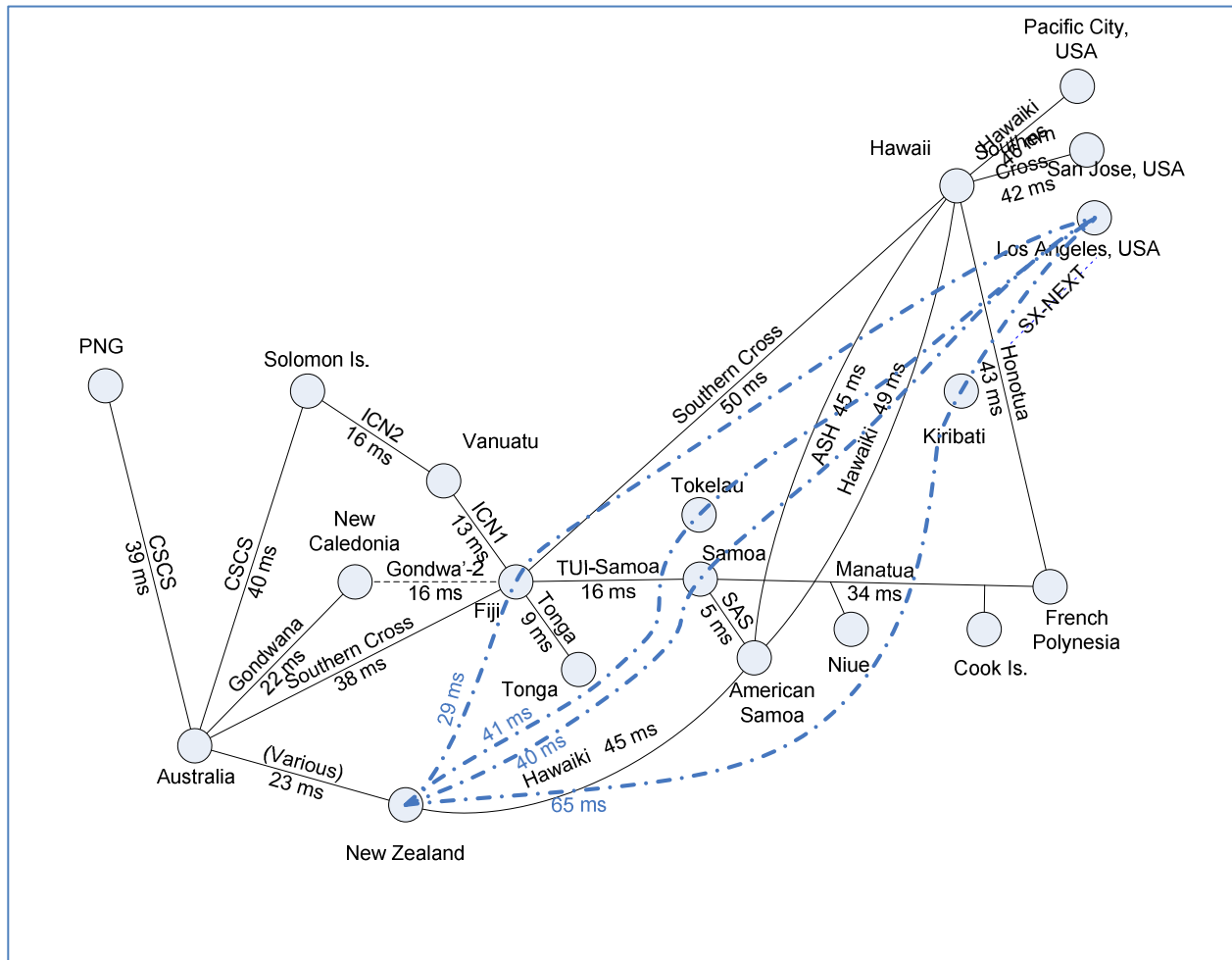


Figure 7 - Southern Pacific Zone cable latency map

In Figure 7 above, the map of cables in this areas has been simplified by removing all the cables that pass through the region but do not connect to any of the island nations. Each active cable is scaled in length and identified by the round-trip-time latency, measured in milliseconds, directly between each nation along each cable.

Feasibility and Location of proposed Pacific IX

Note the future SX-NEXT cable, anticipated to be completed in 2022, marked in blue. SX-NEXT includes spur-cables to Kiribati, Tokelau, Samoa and Fiji. As explained in detail in Chapter 5.3 below, for the purposes of this study each spur island link can only connect directly with the fibre-pair endpoints in New Zealand and near Los Angeles, USA – the islands on spur cables cannot communicate directly with each other without the signal being forced to hair-pin via New Zealand first, thus increasing the latency for any possible peering link to be longer than simply peering with an IXP in New Zealand. For the purposes of this study, SX-NEXT is treated as four separate cables from the points of view of the island nations on branching-unit spurs, with the latency between the spur cable landing and the New Zealand cable station is marked in blue.

An aggregated Pacific Island IXP should be located at the point that minimises the latency, on average, from the collection of island nations that will connect to it. Visually, this diagram suggests either Fiji or Samoa might be locations where the average latency from all southern island nations was minimised. However, the fact that many of the island nations traffic must pass through New Zealand to connect to either Fiji or Samoa may indicate that the optimum location may be in or close to New Zealand.

2.4. Southern Zone – Minimised Weighted Latency Centroid

To identify the optimum location, for each candidate location we calculate the latency of the shortest path from every other island nation (in the southern zone) to the candidate location.

This latency is then weighted by the size of the Internet-using population in each nation, to ensure the peering location selected is closest to the main population centres, thus optimising the overall benefit for the greatest number of citizens. This is done by multiplying the latency to the candidate location by the 'Internet users', and then dividing by the sum of all Internet users across all twelve countries. The best candidate for hosting the Pacific IX is the candidate with the lowest average 'weighted latency' score from all other Pacific nations in the southern zone.

The weighted scores for the candidate locations of Fiji, Samoa and New Zealand are given in the table below:

Feasibility and Location of proposed Pacific IX

Country	Population	Internet Users	Latency to NZ	Weighted Latency	Latency to Fiji	Weighted Latency	Latency to Samoa	Weighted Latency
Fiji	926276	425680	29	11.24	0	0.00	16	6.20
New Caledonia	282754	201000	45	8.24	60	10.98	32	5.86
French Polynesia	290373	195275	74	13.16	50	8.89	34	6.05
Solomon Is	660121	69859	58	3.69	29	1.84	45	2.86
Vanuatu	288037	66613	42	2.55	13	0.79	29	1.76
Samoa	201316	58508	40	2.13	16	0.85	0	0.00
Tonga	106398	42552	38	1.47	9	0.35	25	0.97
American Samoa	50826	17000	45	0.70	21	0.33	5	0.08
Kiribati	109367	14649	65	0.87	94	1.25	105	1.40
Cook Is	11700	5160	66	0.31	42	0.20	26	0.12
Niue	1618	1090	44	0.04	20	0.02	4	0.00
Tokelau	1285	805	41	0.03	70	0.05	81	0.06
TOTAL	2930071	1098191	54.08	44.42	41.75	25.55	41.25	25.36
				NZ		FIJI		SAMOA

Figure 8 - average 'Weighted Latency' to three candidate locations

All other island candidates have higher average weighted latencies, indicating these three candidates are the best candidates.

The 'weighted latency' of 44.42 ms for New Zealand as the Pacific IX is significantly higher than other locations, indicating longer paths on average from other nations, and likely higher transmission costs as well.

The 'weighted latency' score for Fiji and Samoa candidate locations of 25.55 and 25.36 are within less than 1% difference, indicating both locations are equally desirable for hosting the Pacific IX. For each of these candidates the unweighted average latency from other nations (41.75 ms and 41.25 ms) is also extremely close, and cannot identify a clear preferred candidate.

2.5. Case for a 'Distributed IX'

There is no technical reason why an IXP needs to be located in a single physical location. Many large IXPs are distributed in multiple locations and multiple datacentres, consisting at each location of a set of high speed Ethernet switches, linked to the switches in other datacentres by high-speed trunk transmission, usually dark fibre links within the same city.

One example of an IXP spread across multiple cities and managed as a distributed IXP fabric is AMS-IX (Amsterdam IX)³, spread across 12 different datacentres within the greater Amsterdam area, and with partner arrangements that enable any network to connect from other European cities, from the USA, Hong Kong and over 500 other global locations⁴.

³ https://en.wikipedia.org/wiki/Amsterdam_Internet_Exchange

⁴ <https://www.ams-ix.net/ams/where-to-connect>

Feasibility and Location of proposed Pacific IX

In Australia, the 'Australia IX' nodes in each capital city are distributed amongst every major datacentre in each capital city, but are interconnected within the city and form a distributed IX infrastructure where a participant at one datacentre can establish a peering link with a participant at a different datacentre.

RemIX⁵ is a Distributed Internet Exchange for Remote and Rural Networks in Scotland.

The advantages of a distributed IXP is that traffic between participating ISPs is kept as local as possible – two ISPs connecting at the same location will have their traffic kept within that location and exchanged with the lowest latency, and this traffic will not have to traverse any interconnecting links. Two ISPs that connect to different locations (termed 'Points of Presence', or PoPs) will exchange traffic directly between those two locations, but still within the region, on the shortest available path between the PoPs.

With appropriate cost-sharing arrangements in place, this can also be a much more efficient means of aggregating the traffic demands from multiple providers and achieving economies of scale with some long-distance costs, as the demands from each nation can be pooled together to contribute to acquiring a single link between the PoPs, rather than every provider being required to procure an individual, much lower capacity link to a further IXP PoP.

The disadvantages of a distributed IXP architecture are working out an acceptable model for sharing the costs of the transmission bandwidth linking the various PoPs together, and the increased complexity of managing and monitoring the IXP scattered across multiple physical locations.

In the situation of the southern Pacific island states, we observe that many of them, to connect to either Fiji or Samoa, will have to traverse through New Zealand first. There are already major IXPs active in New Zealand, so such a nation will probably achieve better traffic flows and lower circuit costs by connecting to one or more New Zealand IXPs, and NOT participating in the Pacific IX. Such a situation would then deprive the other nations of the benefits of having those countries connected to the Pacific IX.

In addition, one of the goals of establishing the Pacific IX is to attract the global content networks to the aggregate size of the Pacific island networks and have them establish content nodes directly connected to the Pacific IX. The majority of the global content networks are already connected to the New Zealand IXPs, so this goal would largely be achieved if the Pacific IXP was to incorporate connectivity with the New Zealand IXPs in any case.

This leads to a proposed architecture for the Pacific IX that includes PoPs in Fiji, Samoa, and New Zealand, with the New Zealand PoP being co-located with one of the existing major IXPs in New Zealand.

⁵ <https://ec.europa.eu/digital-single-market/en/news/good-practice-remix-distributed-internet-exchange-remote-and-rural-networks-scotland>

Feasibility and Location of proposed Pacific IX

Country	Population	Internet Users	Latency to NZ	Weighted Latency	Latency to Fiji	Weighted Latency	Latency to Samoa	Weighted Latency	Latency to closest	Weighted Latency
Fiji	926276	425680	29	11.24	0	0.00	16	6.20	0	0.00
New Caledonia	282754	201000	45	8.24	60	10.98	32	5.86	32	5.86
French Polynes	290373	195275	74	13.16	50	8.89	34	6.05	34	6.05
Solomon Is	660121	69859	58	3.69	29	1.84	45	2.86	29	1.84
Vanuatu	288037	66613	42	2.55	13	0.79	29	1.76	13	0.79
Samoa	201316	58508	40	2.13	16	0.85	0	0.00	0	0.00
Tonga	106398	42552	38	1.47	9	0.35	25	0.97	9	0.35
American Samoa	50826	17000	45	0.70	21	0.33	5	0.08	5	0.08
Kiribati	109367	14649	65	0.87	94	1.25	105	1.40	65	0.87
Cook Is	11700	5160	66	0.31	42	0.20	26	0.12	26	0.12
Niue	1618	1090	44	0.04	20	0.02	4	0.00	4	0.00
Tokelau	1285	805	41	0.03	70	0.05	81	0.06	41	0.03
TOTAL	2930071	1098191	54.08	44.42	41.75	25.55	41.25	25.36	26.67	15.99
				NZ		FIJI		SAMOA		All THREE

Figure 9 - Extended 'weighted average latency' table for three-location Distributed IX

Above is the weighted average latency score if we establish a three-location distributed IXP, and each country connects to their nearest PoP in Fiji, Samoa or New Zealand. The resulting score (rounded to 16) is significantly lower again than that of either Fiji or Samoa individually, and is a significantly fairer architecture for those countries that would have the longer, more expensive paths to reach Fiji or Samoa to connect to a Pacific IXP PoP there.

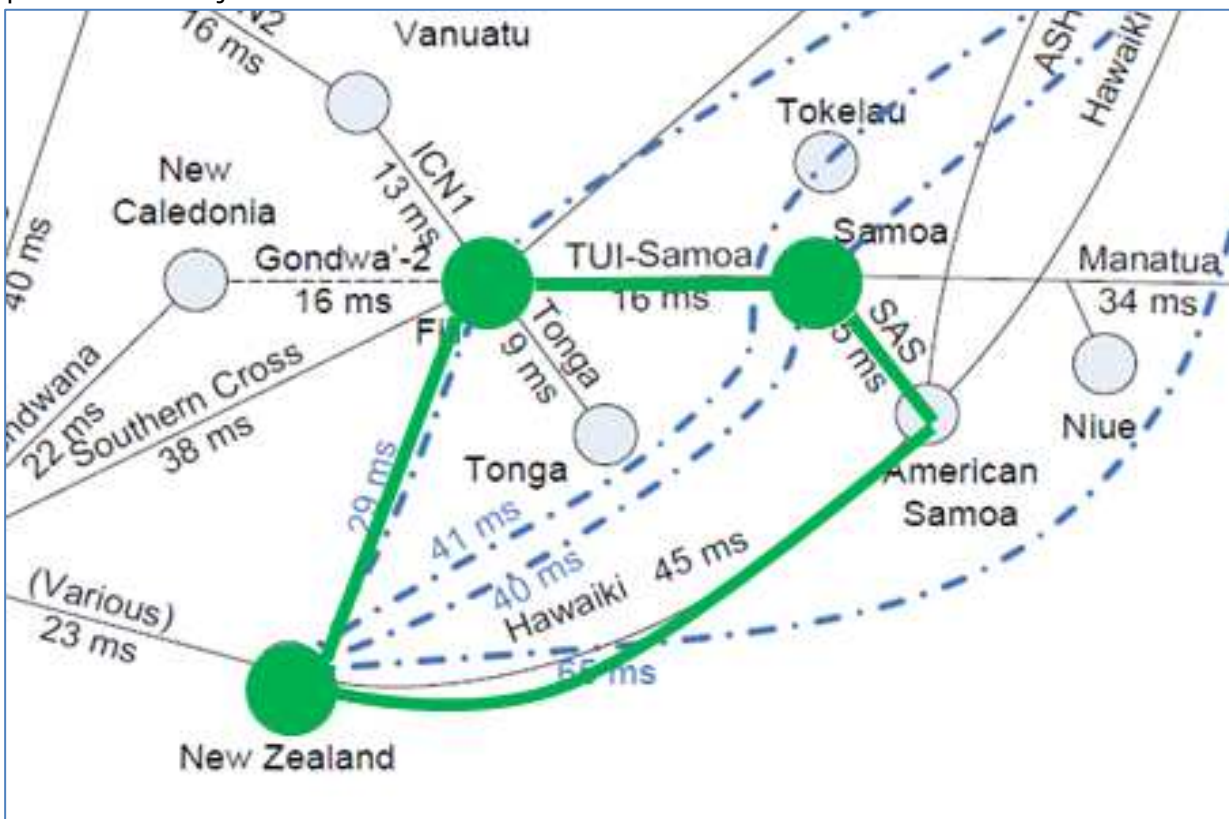


Figure 10 - Proposed distributed Pacific IX 'ring'

Feasibility and Location of proposed Pacific IX

With this architecture, we suggest establishing the three nodes, and linking them through three diverse cable paths in a triangular ring, with sufficient capacity on each path to ensure the aggregate traffic does not suffer congestion.

- The Fiji-Samoa link should be established on the TUI-Samoa cable, with latency of 16 milliseconds.
- The Fiji-New Zealand link should be established on the new Southern Cross NEXT cable when it is delivered in 2022, with predicted latency of 29 milliseconds.
- The Samoa-New Zealand link should be carried on SAS to American Samoa and then Hawaiki to New Zealand. This link should not use the SX-NEXT cable when it comes online, as then both links into New Zealand would be on the same physical cable segment, and subject to a cable cut breaking the distributed IXP.

This architecture provides protection against a cable fault, as a breakage in any one cable leg will enable the traffic that was on that path can re-route around the remaining cables and maintain connectivity, providing resilience against a single cable break.

In New Zealand, most major cities have at least one IXP, with two main operators of IXPs throughout NZ – the NZIX ExchangeNET owned and operated by Citylink, and the New Zealand Internet Exchange facilities, operated by the not-for-profit NZ Internet Exchange Inc.

NZIX ExchangeNET - NZIX

URL: <http://www.nzix.net>

Operated by CityLink – who operates several open-access IXPs in Auckland, Christchurch and Wellington. Each is highly distributed across hundreds of buildings and datacentres

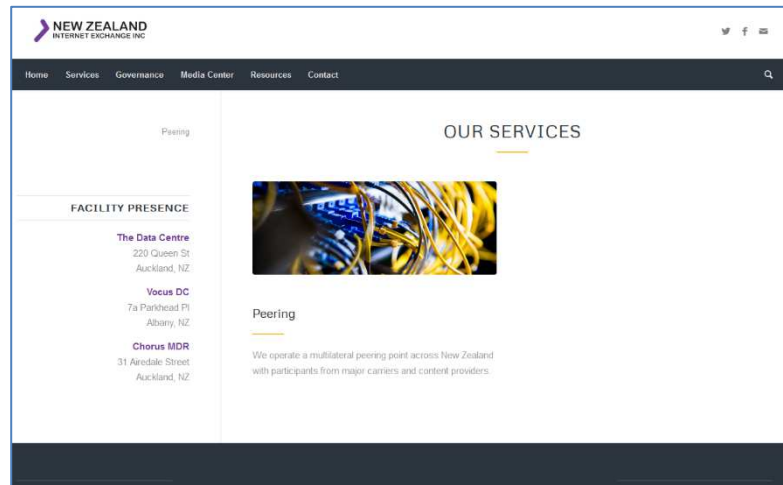


Feasibility and Location of proposed Pacific IX

New Zealand Internet Exchange Inc

URL: <https://ix.nz/>

NZ Internet Exchange Inc is a not-for-profit society that offers carrier-neutral peering points across New Zealand. The Auckland exchange has over 80 ISPs currently connected and exchanging traffic



Country Review – Northern Zone

3. Country Review – Northern Zone

Pacific Island nations in the northern cable zone include:

- Federated States of Micronesia
- Marshall Islands
- (Nauru – not connected by cable)
- Northern Marianas Islands
- Palau
- Papua New Guinea.

Nauru is the only country not connected by an existing subsea telecommunications cable. All other nations are connected via subsea optical fibre cable to Guam, which forms a hub for this zone.

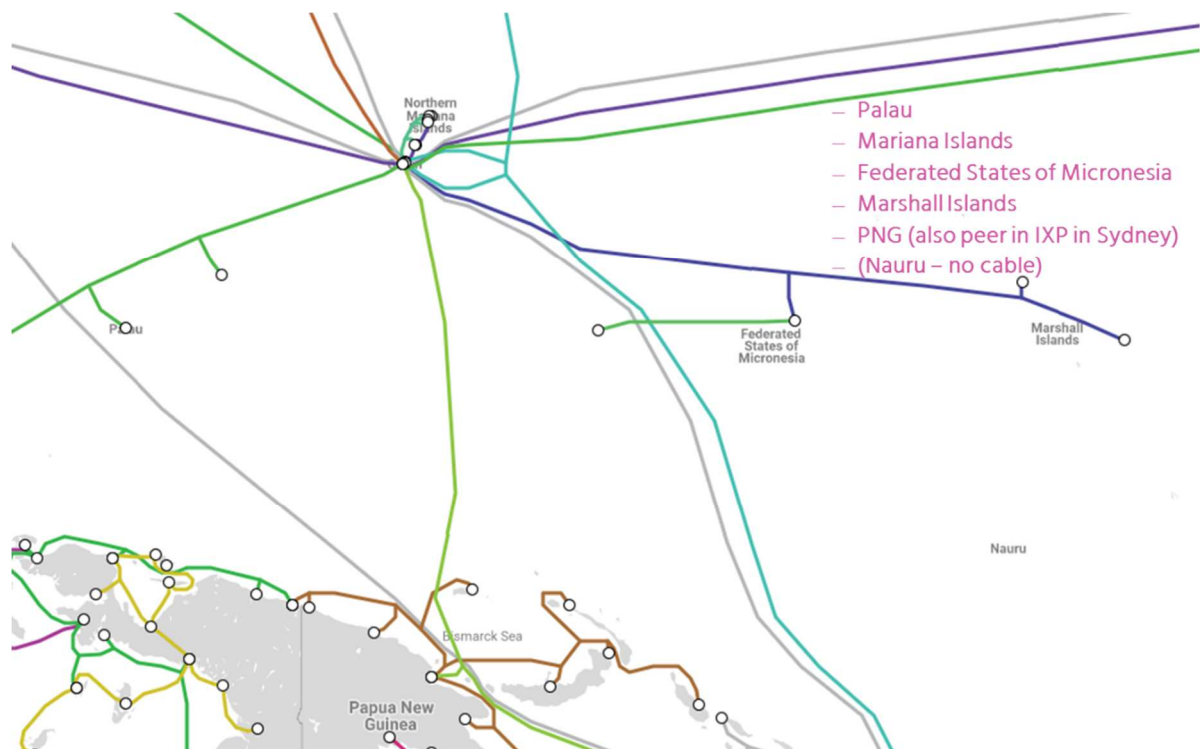


Figure 11 - northern Pacific zone, hubbed via Guam (source: Telegeography)

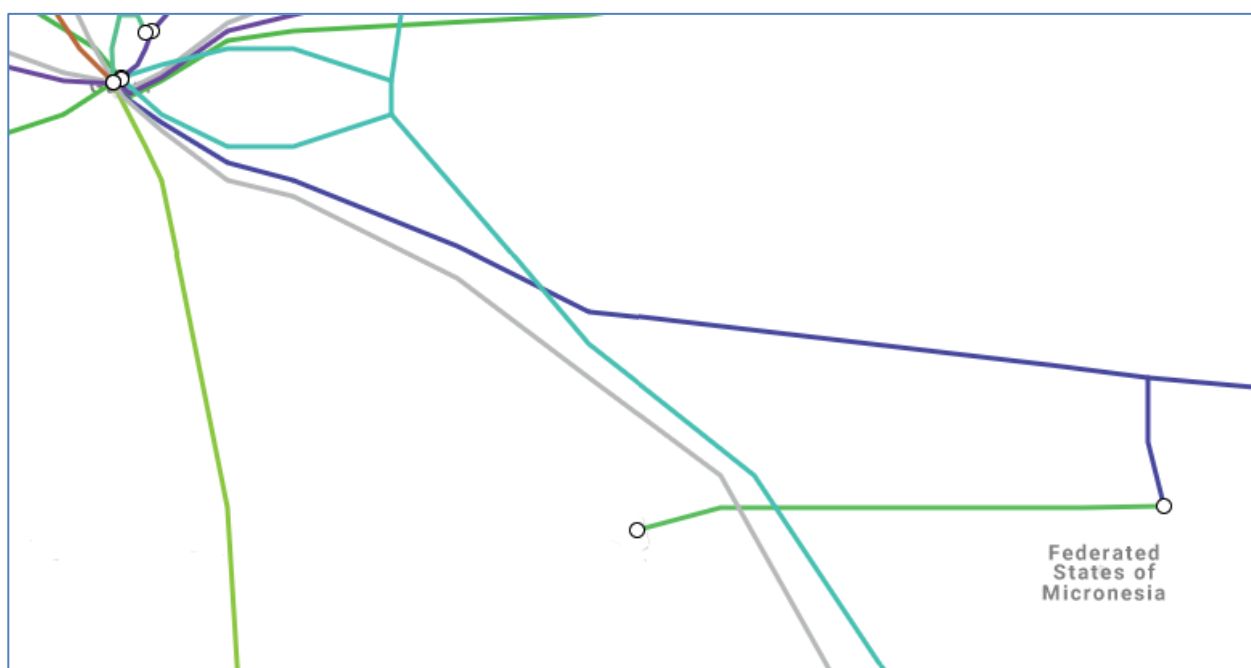
In this study, Nauru is included in the northern zone as the closest connected nation to Nauru is the Marshall Islands, so a future cable to the Marshall Islands to link up to the HANTRU1 cable would be the lowest cost route to connect Nauru by subsea optical fibre. Alternatively, a future cable from Guam past Nauru and Tuvalu (which is also currently unconnected) to one or more of the southern zone nations would help connect Nauru and Tuvalu, and also form a robust alternative diverse path for Pacific Ocean triangle of trunk cables that could be used as a protection path if the cables to/from Hawaii were to fail.

Country Review – Northern Zone

This section details the international connectivity of each Pacific Islands nation in the Northern zone, concentrating on:

- International connectivity via low-latency subsea cables (domestic cables are not detailed)
- Adjacency Matrix – other countries directly connected, capacity and latency
- Location and operator/owner of international gateway infrastructure
- Any existing IXP (Internet Exchange Point) infrastructure
- Latency performance from surrounding content hubs (Sydney, Auckland, Singapore, US West Coast)

3.1. Federated States of Micronesia (.fm)



Federated States of Micronesia (FSM) is currently connected by one international subsea cable.

The **HANTRU1 cable**, commissioned in 2010, was built and partially funded by Hannon Armstrong Capital LLC for the US Army between Guam and Kwajalein in Marshall Islands, with one fibre-pair dedicated to this use. A second fibre-pair was funded and is jointly owned by the FSM Telecommunications Company and the Marshall Islands Telecommunications Authority, with a branch to Pohnpei in FSM.

3.1.1. International Cable Connectivity

Cable Name (RFS)	Owner	Destinations	Capacity	Latency
HANTRU1		Piti, Guam, USA	20 Gbps (up to 160 Gbps)	12

Country Review – Northern Zone

	FSM Telecommunications Company Marshall Islands Telecommunications Authority	Kwajalein, Marshall Islands Majuro, Marshall Islands	20 Gbps (up to 160 Gbps)	21
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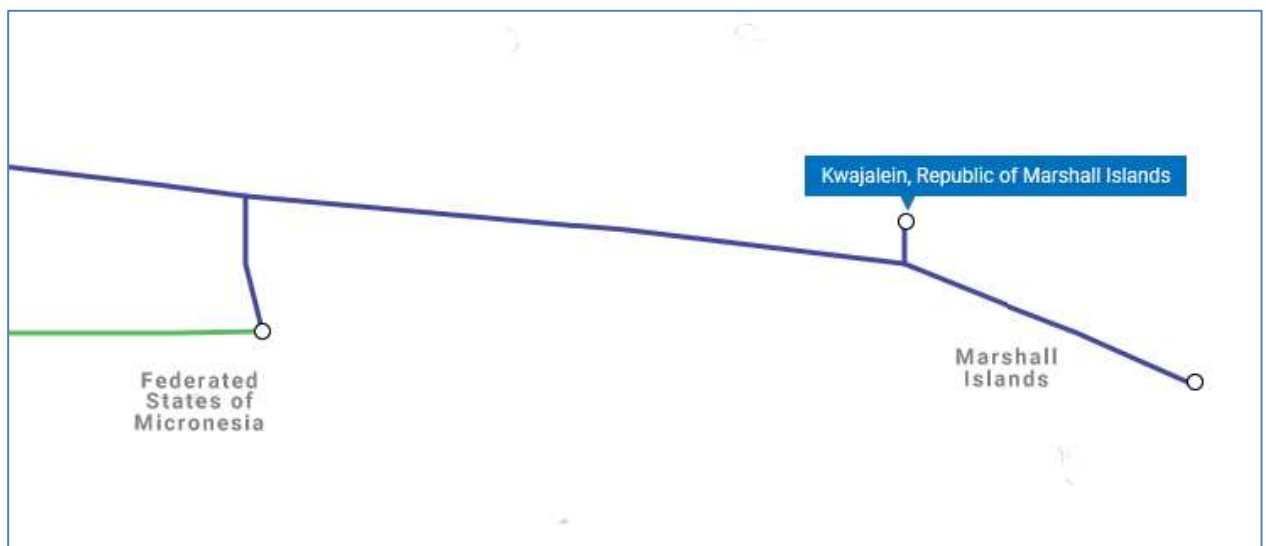
3.1.2. Major International Providers

FSM has a single provider of international connectivity, the FSM Telecommunications Corporation, based in Pohnpei, FSM.

3.1.3. Latency Measurements

Providers – FSM	Latency (round-trip – milliseconds)			
	Sydney	New Zealand	Singapore	USA
FSM Telecommunications Company	279	308	294	123

3.2. Marshall Islands (.mh)



The Republic of the Marshall Islands is currently connected by one international subsea cable.

Country Review – Northern Zone

The **HANTRU1 cable**, commissioned in 2010, was built and partially funded by Hannon Armstrong Capital LLC for the US Army between Guam and Kwajalein in Marshall Islands, with one fibre-pair dedicated to this use. A second fibre-pair was funded and is jointly owned by the FSM Telecommunications Company and the Marshall Islands Telecommunications Authority, with a branch to Pohnpei in FSM and an extension to a second landing in the Marshall Islands on Majuro.

3.2.1. International Cable Connectivity

Cable Name (RFS)	Owner	Destinations	Capacity	Latency
HANTRU1	FSM Telecommunications Company Marshall Islands Telecommunications Authority	Piti, Guam, USA	20 Gbps (up to 160 Gbps)	33
		Pohnpei, FSM	20 Gbps (up to 160 Gbps)	21

3.2.2. Major International Providers

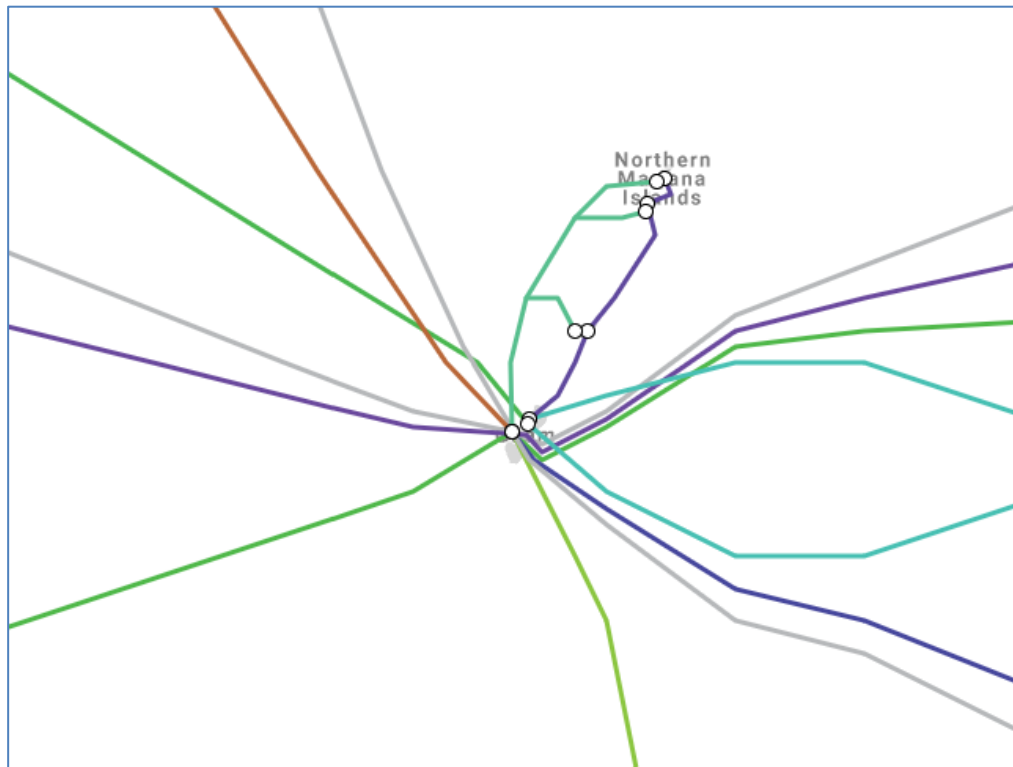
The Marshall Islands has a single provider of international connectivity, the Marshall Islands National Telecommunications Authority.

3.2.3. Latency Measurements

Providers – FSM	Latency (round-trip – milliseconds)			
	Sydney	New Zealand	Singapore	USA
Marshall Islands National Telecommunications Authority	201	235	132	146

Country Review – Northern Zone

3.3. Northern Mariana Islands (.mp)



The Commonwealth of the Northern Mariana Islands is currently connected by two international subsea cables to the nearby island of Guam.

The original **Mariana-Guam cable**, commissioned in 1997, connects the three main populated islands of Saipan, Tinian and Rota within the Northern Marianas to Guam. It is owned and operated by IT&E Corp, a provider of services in Guam and the Marianas.

The **Atisa cable**, 280 kilometres long and owned by Docomo Pacific, was installed in 2017, and provides additional capacity and diversity in case of a cable breakage, connecting the same three islands to Guam.

3.3.1. International Cable Connectivity

Cable Name (RFS)	Owner	Destinations	Capacity	Latency
Mariana-Guam	IT&E	Piti, Guam, USA (from Saipan, CNMI)	?	5

Country Review – Northern Zone

Atisa	Docomo Pacific	Pita, Guam, USA (from Saipan, CNMI)	200 Gbps (up to 7.2 Tbps)	6
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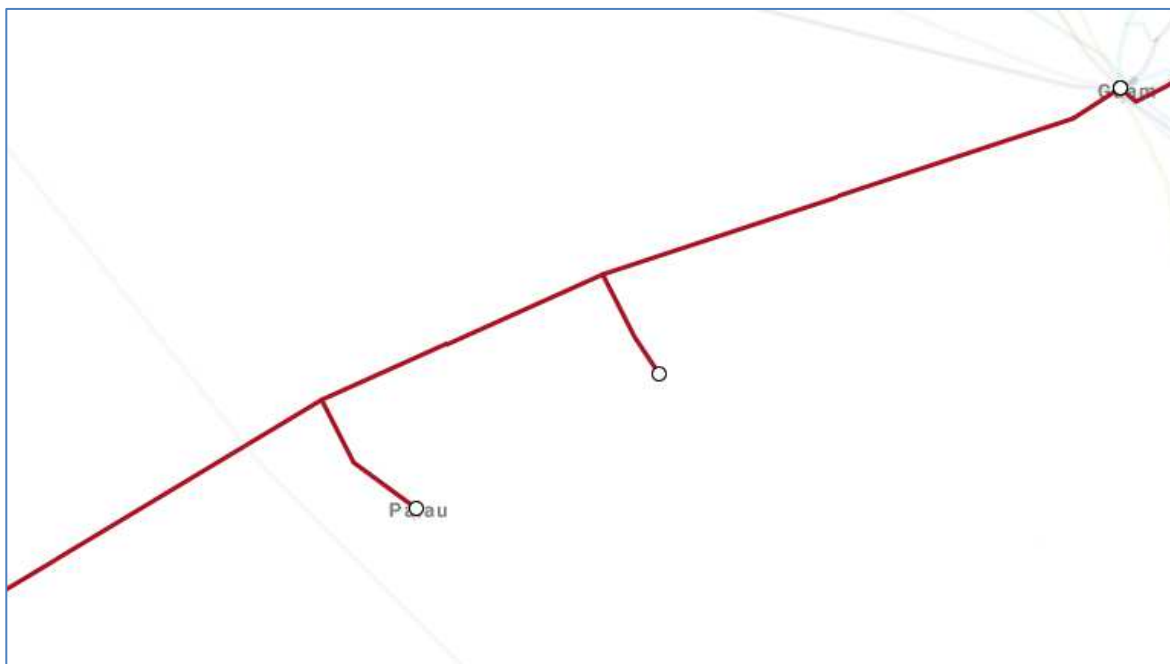
3.3.2. Major International Providers

The Commonwealth of the Northern Mariana Islands has two providers of international connectivity, namely the owners of each cable.

3.3.3. Latency Measurements

Latency measurements to locations within Saipan were not able to be performed as IP addresses could not be verified to be physically served within that location. As a proxy, latencies to Guam, plus 5 milliseconds, should be used.

3.4. Palau (.pw)



Palau is currently connected on a spur cable off the SEA-US cable, which connects The Philippines and Indonesia in the west with Guam, Hawaii and onwards to the mainland USA to the east.

The **SEA-US cable**, commissioned in 2017, links the five areas and territories of Manado in Indonesia, Davao in Southern Philippines; Piti in the territory of Guam; as well as Honolulu (on the island of Oahu), Hawaii; and Los Angeles, California in the continental USA.

Country Review – Northern Zone

The spur to Palau and an optical fibre wavelength between Palau and Guam was funded by loans from the Asian Development Bank, and the spur is owned and operated by the Belau Submarine Cable Corporation (BSCC), formed in 2016 by the government of Palau as the Palau international connectivity manager. The Palau Spur has an initial design capacity of 500 Gigabits per second (Gbps).

3.4.1. *International Cable Connectivity*

Cable Name (RFS)	Owner	Destinations	Capacity	Latency
SEA-US / Palau Spur	Belau Submarine Cable Corporation	Piti, Guam, USA	500 Gbps	36

3.4.2. *Major International Providers*

Palau's BSCC is the single provider of international connectivity

3.4.3. *Latency Measurements*

Providers – Palau	Latency (round-trip – milliseconds)			
	Sydney	New Zealand	Singapore	USA
BSCC	203	233	117	200

Country Review – Northern Zone

3.1. Papua New Guinea (.pg)

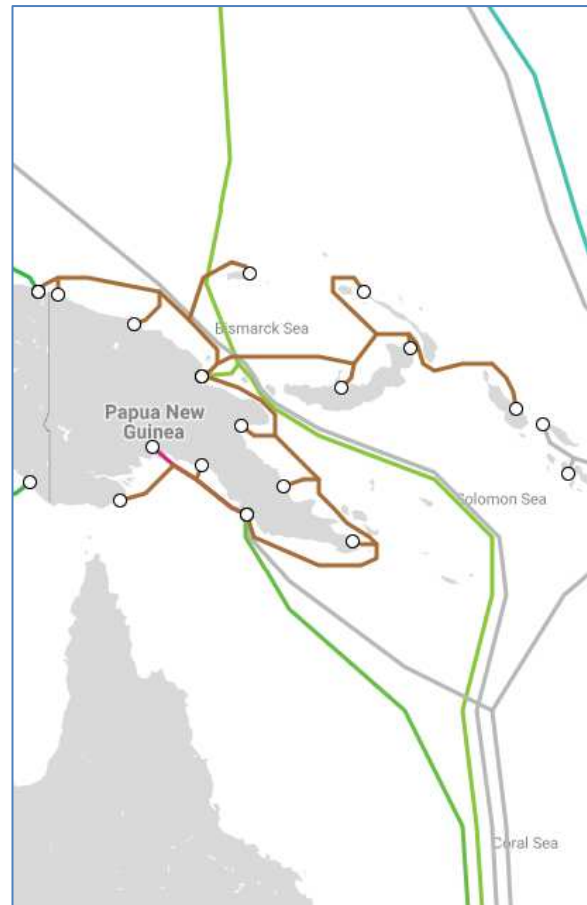
Papua New Guinea (PNG) is relatively well connected in the north-south direction, with three separate cables connecting PNG to Australia, one of which also connects PNG with Guam to the north.

The **APNG2 cable** was put into service in 2006, between Port Moresby and Sydney, Australia. APNG2 was created from sections of the decommissioned PACRIM-WEST cable that earlier connected Australia to Guam and Singapore. It uses older PDH technology over two fibre-pairs yielding a total of 1.1 Gbps of capacity (2 x 565 Mbps).

The **PPC-1 cable** was put into service in 2009, built by Australian telecommunications carrier Pipe Networks, linking Sydney, Australia to Medang, PNG and onwards to Guam. PPC-1 consists of two fibre-pairs, with a total capacity of ~ 3 Tbps. It is now owned and operated by TPG Telecom in Australia.

Most recently the **Coral Sea Cable System** was constructed in 2019, with two fibre pairs between Port Moresby and Sydney, and a further two fibre-pairs between the Solomon Islands and Sydney, providing many Tbps of capacity (potentially up to 15 Tbps on each fibre-pair). Note there are no fibres directly between PNG and Solomon Islands – all connectivity between these nations must transit through Sydney first.

Also constructed and in service in 2019 is a PNG domestic festoon cable linking 13 coastal towns in PNG and Jayapura in Indonesia.



3.1.1. International Cable Connectivity

Cable Name (RFS)	Owner	Destinations	Capacity	Latency
APNG2	Telekom PNG Telstra International	Sydney, Australia	1.1 Gbps	22
PPC-1	TPG Telecom Ltd	Sydney, Australia	3 Tbps	36
		Piti, Guam, USA	3 Tbps	23
Coral Sea Cable System	CSC Consortium	Sydney, Australia	50 Tbps	22

Country Review – Northern Zone

3.1.2. Major International Providers

PNG's Telekom PNG is the single provider of international connectivity

3.1.3. Latency Measurements

Providers – PNG (Port Moresby)	Latency (round-trip – milliseconds)			
	Sydney	New Zealand	Singapore	USA
Telekom PNG	100	131	117	224

3.1.4. PNG Internet Exchange

The PNG-IXP⁶ is a not-for-profit independent neutral IXP established in 2017 and hosted by PNG's telecommunication regulator, the National Information and Communications Technology Authority (NICTA). The facilities are located in an open-access neutral datacentre, ensuring as many parties as possible can connect.

PNG-IXP reports 25+ members are interconnected, as of 2017.

The development of the PNG-IXP was a collaborative effort lead by NICTA, with technical advice and assistance from ISOC and APNIC⁷.

⁶ <http://www.pgix.org.pg/>

⁷ <https://blog.apnic.net/2017/04/20/launching-papua-new-guineas-first-neutral-ixp/>

Country Detailed Review – Southern Zone

4. Country Detailed Review – Southern Zone

Pacific Island nations in the southern cable zone includes:

- American Samoa
- Cook Islands
- Fiji
- French Polynesia
- Kiribati
- New Caledonia
- Niue
- Samoa
- Solomon Islands
- Tokelau
- Tonga
- Vanuatu

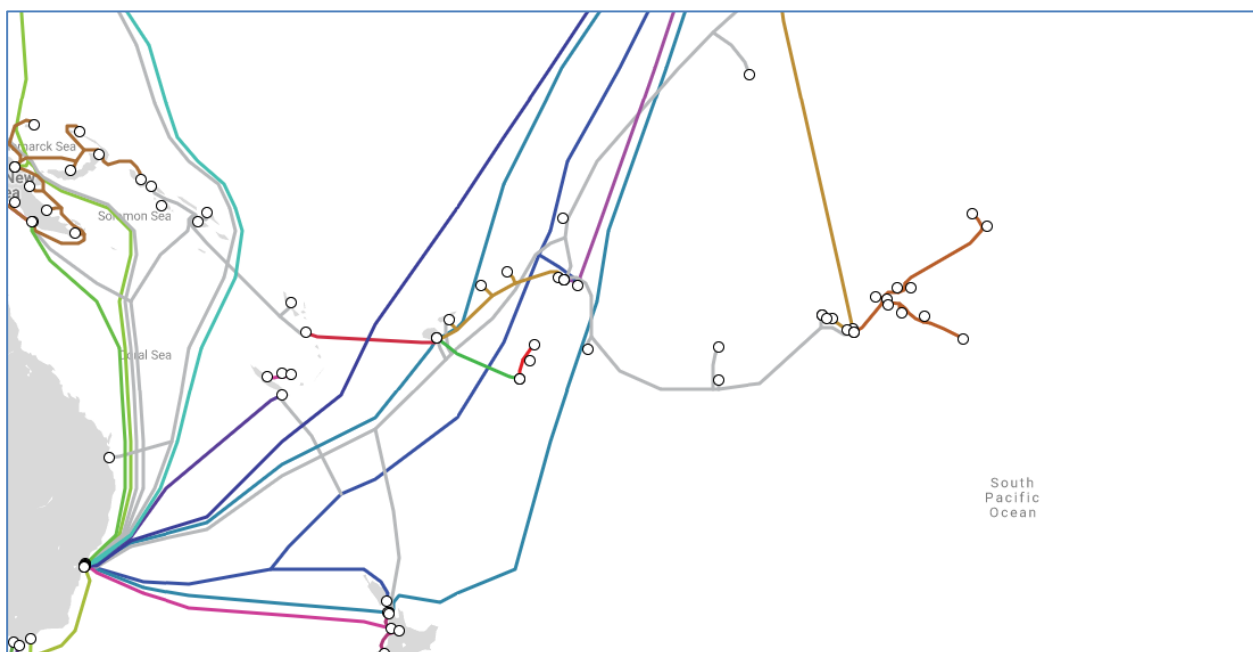


Figure 12 – southern Pacific zone, between Australia, New Zealand and Hawaii (source: Telegeography)

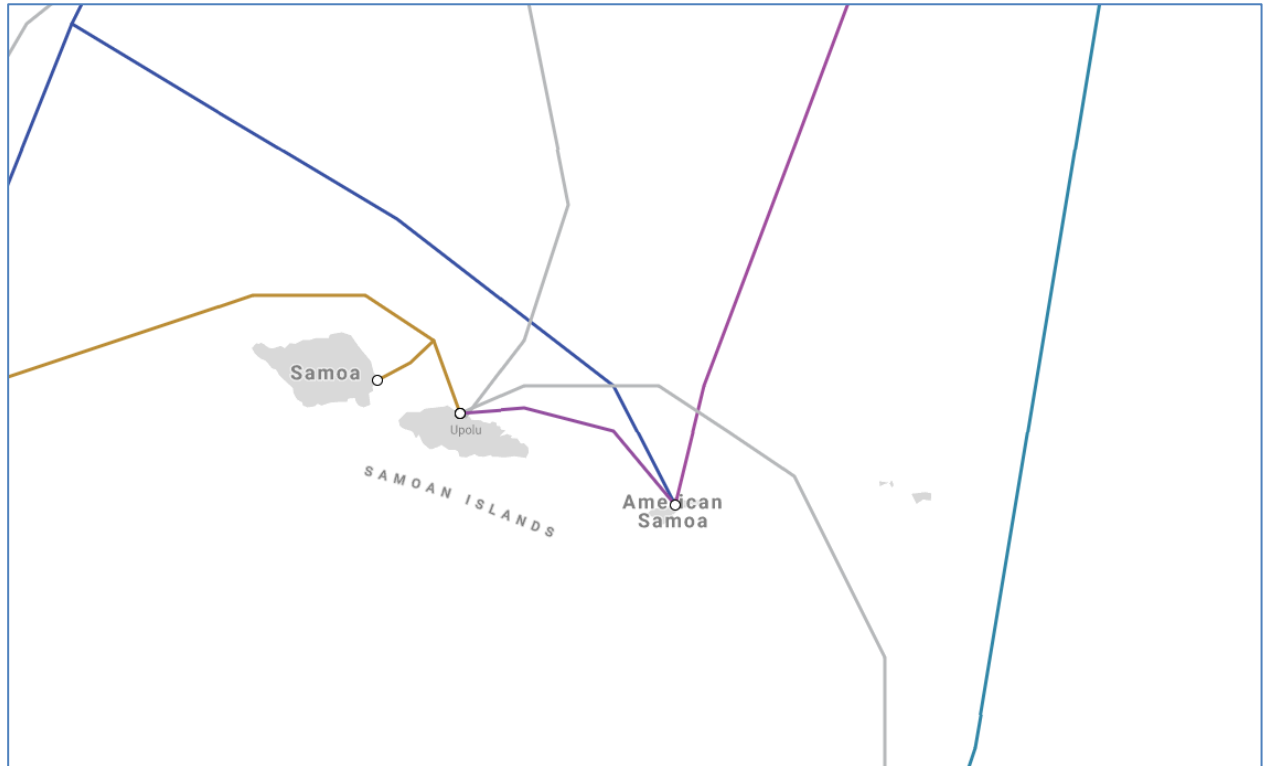
This section details the international connectivity of each Pacific Islands nation in the Southern zone, concentrating on:

- International connectivity via low-latency subsea cables
- Adjacency Matrix – other countries directly connected, capacity and latency

Country Detailed Review – Southern Zone

- Location and operator/owner of international gateway infrastructure
- Any existing IXP (Internet Exchange Point) infrastructure
- Latency performance from surrounding content hubs (Sydney, Auckland, Singapore, US West Coast)

4.1. American Samoa (.as)



American Samoa is currently connected by three separate international subsea cables.

The **American Samoa – Hawaii cable (ASH)**, commissioned in 2009 from a section of a decommissioned PacRim-East cable, provides just 1.12 Gbps capacity in a point-to-point configuration between Pago Pago, American Samoa and Keawaula, Hawaii. ASH Cable LLC is 66% owned by Fiji's Amalgamated Telecommunications Holdings Limited (ATH), and 33% owned by the Government of American Samoa.

The **Samoa-American Samoa cable (SAS)** was also commissioned in 2009 and is also owned by ASH Cable LLC, linking Pago Pago with Apia, Samoa. It was recently upgraded to 100 Gbps capacity. ASH and SAS are often referred to as a single ASH-SAS cable system.

Hawaiki Cable links mainland USA (Portland, Oregon), Hawaii, Australia and New Zealand, with a one-fibre-pair spur to American Samoa at Pago Pago, was commissioned and became Ready For Service in July 2018. The American Samoa spur provides a single wavelength connection with 100 Gbps capacity towards Hawaii and mainland USA, and 100 Gbps capacity on a trunk fibre-pair to New Zealand. Due to the topology of the optical fibres within the cable, the American Samoa spur does not directly link to Australia.

Country Detailed Review – Southern Zone

4.1.1. International Cable Connectivity

Cable Name (RFS)	Owner	Destinations	Capacity	Latency
American Samoa-Hawaii (ASH) Cable	ASH Cable LLC	Keawaula, Hawaii, USA	1.12 Gbps	46
Samoa-American Samoa (SS) cable	ASH Cable LLC	Apia, Samoa	100 Gbps	7
Hawaiki Cable	Hawaiki trunk, spur owned by American Samoa TeleCommunications Authority (ASTCA)	Hawaii / Los Angeles, USA	100 Gbps	47 / 90
		New Zealand	100 Gbps	45

4.1.2. Major International Providers

American Samoa has two primary providers of international connectivity using the subsea cables.

Bluesky (Amalgamated Telecom Holdings (ATH)/American Samoa Telecom LLC (AST)) provides capacity solely from mainland USA using Southern Cross Cable System capacity through Bluesky Samoa, and then onwards to American Samoa using SAS. While the Southern Cross cable connects to multiple locations including Australia, New Zealand and Hawaii, Bluesky does not use these entry points - all traffic from across the globe – including from Australia, New Zealand and Hawaii – must funnel into a datacentre in San Jose, California before being carried to Bluesky's network across a link with round-trip-time minimum 134 milliseconds.

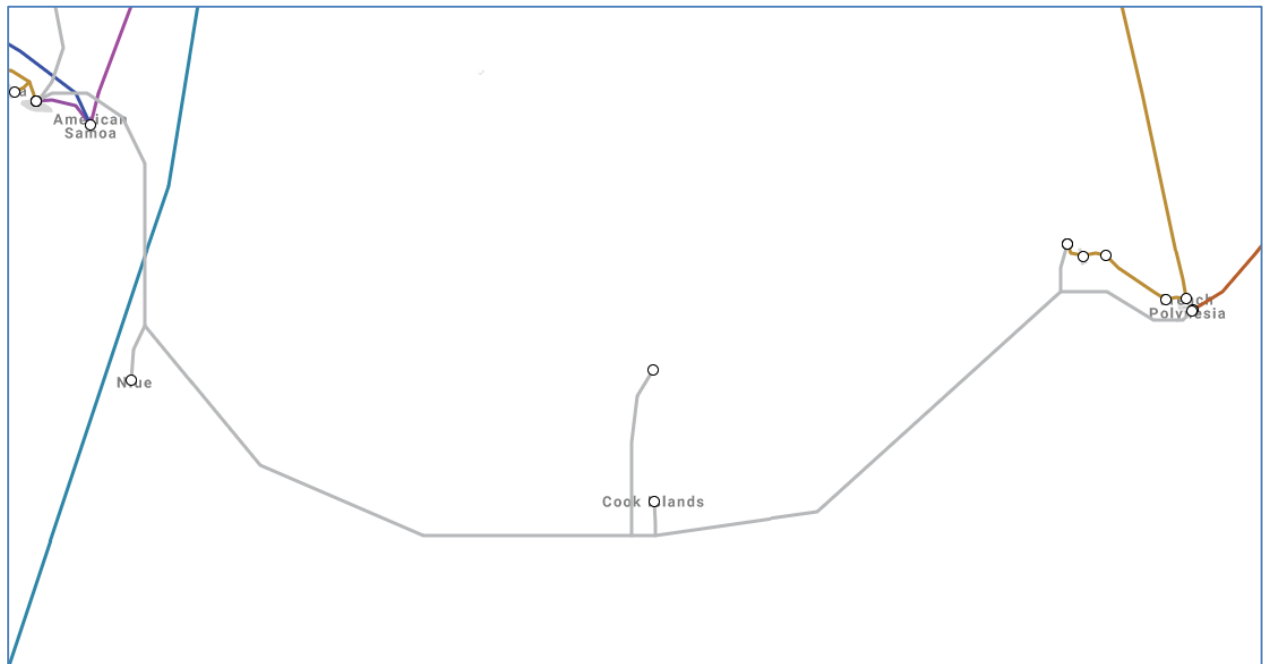
The American Samoa Telecommunications Authority (ASTCA) also provides international connectivity, connecting across the Hawaiki cable from Portland, Oregon, USA and through Hawaii.

4.1.3. Latency Measurements

Providers – American Samoa	Latency (round-trip – milliseconds)			
	Sydney	New Zealand	Singapore	USA
ASTCA	226	249	191	111
BlueSky Pago-Pago	290	308	305	198

Country Detailed Review – Southern Zone

4.2. Cook Islands (.ck)



Cook Islands are not currently connected to an international cable, however one new cable is under construction.

The Manatua cable (RFS Q2 2020) will connect two locations within the Cook Islands as two branches to French Polynesia, Niue and Samoa, with initial design capacity 200 Gbps, and an ultimate capacity of 10 Tbps (depending on detailed fibre topology). The optical fibres from Tahiti and from Samoa will connect into Rarotonga. Another optical-fibre pair within the cable will connect Rarotonga to Aitutaki in Cook Islands as an intra-island service.

Manatua is described as a 2/3 pair main trunk system between French Polynesia and Samoa – the Cook Islands spur will connect to Samoa and to Rarotonga, French Polynesia, and may not be able to connect directly with Niue.

4.2.1. International Cable Connectivity

Cable Name (RFS)	Owner	Destinations	Capacity	Latency
Manatua (under construction RFS 2020)	<i>Manatua Cable Consortium: Avaroa Cable Ltd (.ck) Niue Telecom (.nu) Samoa Submarine Cable Co (.sm) OPT (.pf)</i>	<i>To'ahotu, Tahiti island, French Polynesia</i>	<i>100 Gbps</i>	<i>14</i>
		<i>Alofi, Niue</i>	<i>100 Gbps</i>	<i>18</i>
		<i>Apia, Samoa</i>	<i>100 Gbps</i>	<i>22</i>

Country Detailed Review – Southern Zone

4.2.2. Major International Providers

Cook Islands currently has one international connectivity provider – Bluesky Telecom (formerly Telecom Cook Islands), which is currently connected via two satellite-based networks through O3b and through Speedcast, hubbed from the USA.

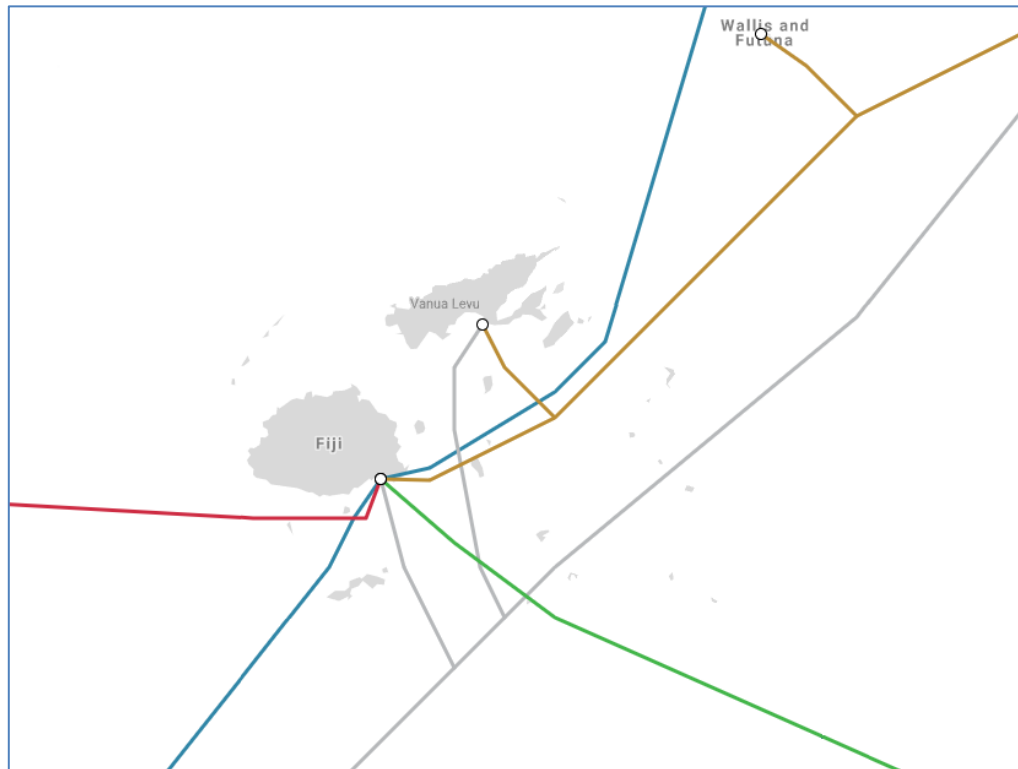
Avaroa Cable Ltd, owned by the Cook Island government, will own and manage the Cook Island landing facilities for the new Manatua cable.

4.2.3. Latency Measurements

Providers – Cook Islands	Latency (round-trip – milliseconds)			
	Sydney	New Zealand	Singapore	USA
(Satellite)	322	337	347	177

Country Detailed Review – Southern Zone

4.3. Fiji (.fj)



Fiji is well connected, with three intra-Pacific cables to other Pacific island nations, one major trans-Pacific cable (Southern Cross Cable System), and a second major trans-Pacific cable (Southern Cross NEXT) due to be connected in 2022.

The **InterChange Cable Network-1 (ICN1)** cable links Fiji with Vanuatu, commissioned in 2014. ICN1 is owned and operated by Interchange Limited based in Vanuatu. The anticipated full capacity is 1280 Gbps.

The **Tonga cable** links Fiji with Tonga, and was established in 2013 and is jointly owned by Government of Tonga (66.6%), Tonga Communications Corporation and Digicel Tonga (16.7% each).

The **TUI-Samoa cable** links Fiji (at two locations) with Samoa (two locations), and Wallis and Futuna islands (two locations), and was commissioned and became Ready For Service in early 2018. TUI-Samoa is a single-fibre-pair cable yielding up to 8 Tbps in 80 x 100 Gbps channels, and is owned and operated by the Samoa Submarine Cable Company.

The **Southern Cross cable** (SCCS) northern leg connects from Fiji west to Sydney, Australia and east to Hawaii, USA and then onward to two locations on the USA mainland. A southern leg forms a ring (not connected to Fiji) from Sydney to New Zealand and then north to Hawaii and mainland USA.

Country Detailed Review – Southern Zone

The **Southern Cross NEXT cable** (RFS Q1 2022) will connect a one-fibre-pair branch cable into Suva, Fiji, and another one-fibre-pair branch cable into Savusavu. Each of these locations will be able to individually connect south-west to New Zealand, and north-east to Los Angeles on the USA mainland. The Suva and Savusavu branches will be on independent wavelengths and will not be able to communicate directly with each other through the SX-NEXT cable. Other branch cables will connect into Samoa, Kiribati, Tokelau and Australia, however the Fijian branch-cables will be on separate wavelengths and unable to connect directly to these locations without passing through New Zealand first.

4.3.1. International Cable Connectivity

Cable Name (RFS)	Owner	Destinations	Capacity	Latency
ICN1	Interchange Ltd (VU)	Port Vila, Vanuatu	1280 Gbps	13
Tonga Cable	Tonga Cable Limited	Nuku`alofa, Tonga	??	9
TUI-Samoa Cable	Samoa Submarine Cable Company	Wallis & Futuna Islands	100 Gbps	8
		Apia, Samoa	100 Gbps	15
Southern Cross (North leg)	Southern Cross Consortium	Sydney, Australia	1000 Gbps	37
		Hawaii	1000 Gbps	24
Southern Cross NEXT (under construction RFS 2022)	Southern Cross Cable Consortium.	Takapuna, New Zealand	100 Gbps	27
	Fiji Branch: Fiji International Telecommunications	Los Angeles, USA	100 Gbps	99

4.3.2. Major International Providers

Fiji has four primary providers of international Internet connectivity using the subsea cables.

Telecom Fiji/Connect Internet Services provides services connected through two upstream providers, FINTEL and Hurricane Electric. The primary path for traffic into Telecom Fiji is via Sydney on Southern Cross cable, with latency ranging from 37 ms to Sydney up to 191 ms from USA, which carries through Sydney before entering Fiji.

Vodafone Fiji provides services through two upstream providers, Telstra Global and Singtel Optus, with at least one of those gateways located in Fiji, as Singtel Optus is a co-owner of Southern Cross Cable. Traffic into Vodafone Fiji from Asia and ANZ travels via Sydney on Southern Cross, while traffic from the USA (and Europe) comes direct from the USA to Fiji on the northern leg of Southern Cross without touching Sydney first, giving Vodafone the best latency performance from USA at 132 milliseconds round-trip delay, and redundancy against a cable break either side of Fiji.

Country Detailed Review – Southern Zone

Fiji International Telecoms (FINTEL) operates the cable landing station infrastructure and international transmission equipment for the subsea cables landing in Fiji. FINTEL also provides Internet services on a wholesale and retail basis with two upstream providers (Cogent Communications and Global Gateway (NZ)). All traffic into Fiji suffers from relatively high latency, as all traffic is carried top the USA before traversing into Fiji via the Southern Cross cable.

Digicel Fiji connects through the facilities of Digicel Australia, with very good performance from ANZ and Asia using the southern leg of Southern Cross cable (45 milliseconds from Australia), while traffic from the USA has latency 192 milliseconds due to being carried all the way to Sydney before tromboning back to Fiji.

4.3.3. Latency Measurements

Providers - Fiji	Latency (round-trip – milliseconds)			
	Sydney	New Zealand	Singapore	USA
Telecom Fiji	37	61	128	191
Vodafone Fiji	40	63	217	132
Fiji International Telecoms	152	177	213	160
Digicel Fiji	35	61	127	189

4.3.4. Fiji – Internet Exchange

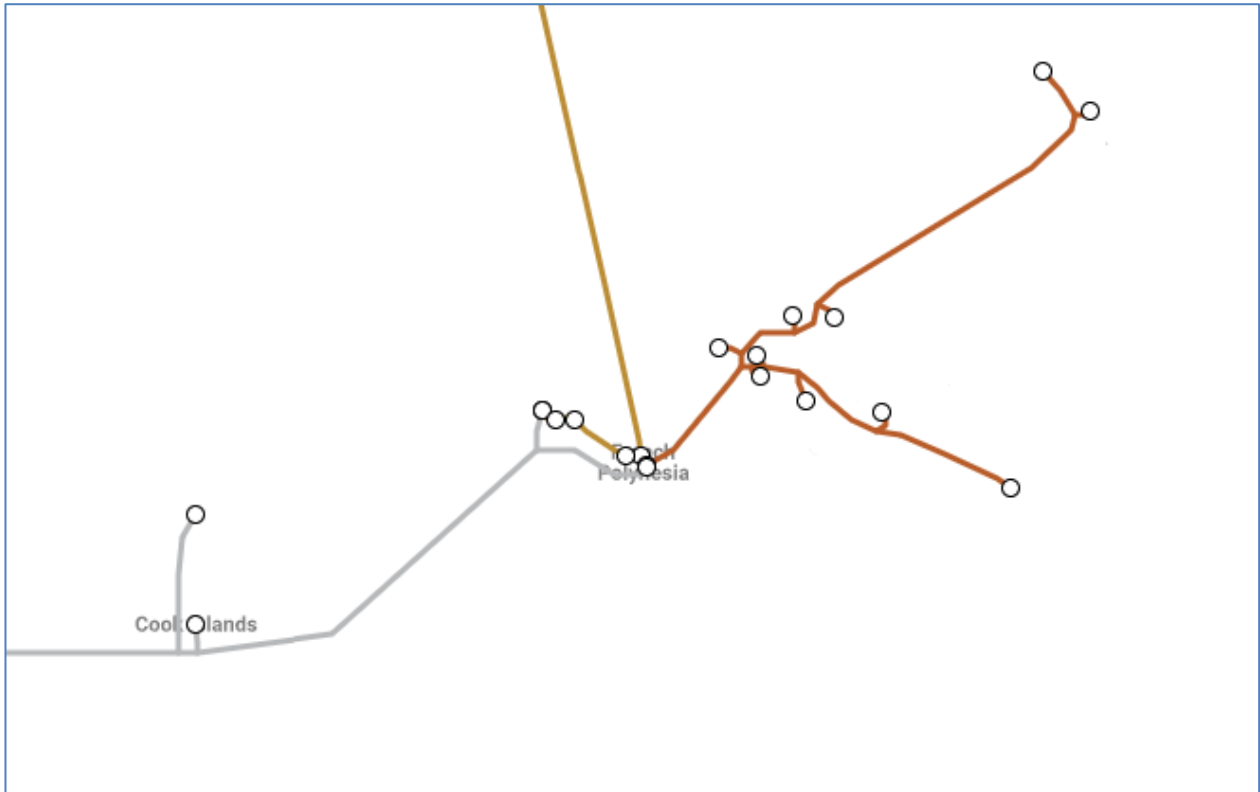
Fiji has an Internet exchange point (IXP) – Fiji-IX⁸, established in 2017⁹, for local interconnectivity amongst Fijian ISPs. Currently four local providers connect to the Fiji-IX, with additional providers pending. Fiji-IX is physically located within the international cable landing station datacentre of FINTEL.

⁸ <http://www.taf.org.fj/Publications/Fiji-IX.aspx>

⁹ <https://blog.apnic.net/2017/12/01/fiji-joins-ix-community/>

Country Detailed Review – Southern Zone

4.4. French Polynesia (.pf)



French Polynesia is currently connected to Hawaii via the Honotua cable, operated by OPT (French Polynesia). An addition, providers also use satellite connectivity through O3b satellite.

A second cable under construction (Manatua, RFS Q1 2020) will connect French Polynesia to the Cook Islands, Niue, and Samoa, with initial design capacity of 200 Gbps.¹⁰

¹⁰ "The 3,166km Manatua Cable will connect Apia (Samoa) to To'ahotu (Tahiti) via a two/three fibre pair trunk, with branching units to Niue, Aitutaki (Cook Islands, one fibre pair), Rarotonga (Cook Islands, three fibre pairs) and Vaitape (French Polynesia, one fibre pair)",

<https://www.telegeography.com/products/commsupdate/articles/2018/11/23/cable-compendium-a-guide-to-the-weeks-submarine-and-terrestrial-developments/>

Country Detailed Review – Southern Zone

4.4.1. International Cable Connectivity

Cable Name (RFS)	Owner	Destinations	Capacity	Latency
Honotua	OPT French Polynesia Ltd (FP)	Hawaii, USA	320 Gbps	43
Manatua (under construction RFS 2020)	Manatua Cable Consortium: Avaroa Cable Ltd (.ck) Nuie Telecom (.nu) Samoa Submarine Cable Co (.sm) OPT (.pf)	Cook Islands	100 Gbps	18
		Nuie	100 Gbps	28
		Apia, Samoa	100 Gbps	34

4.4.2. Major International Providers

French Polynesia has two international connectivity providers:

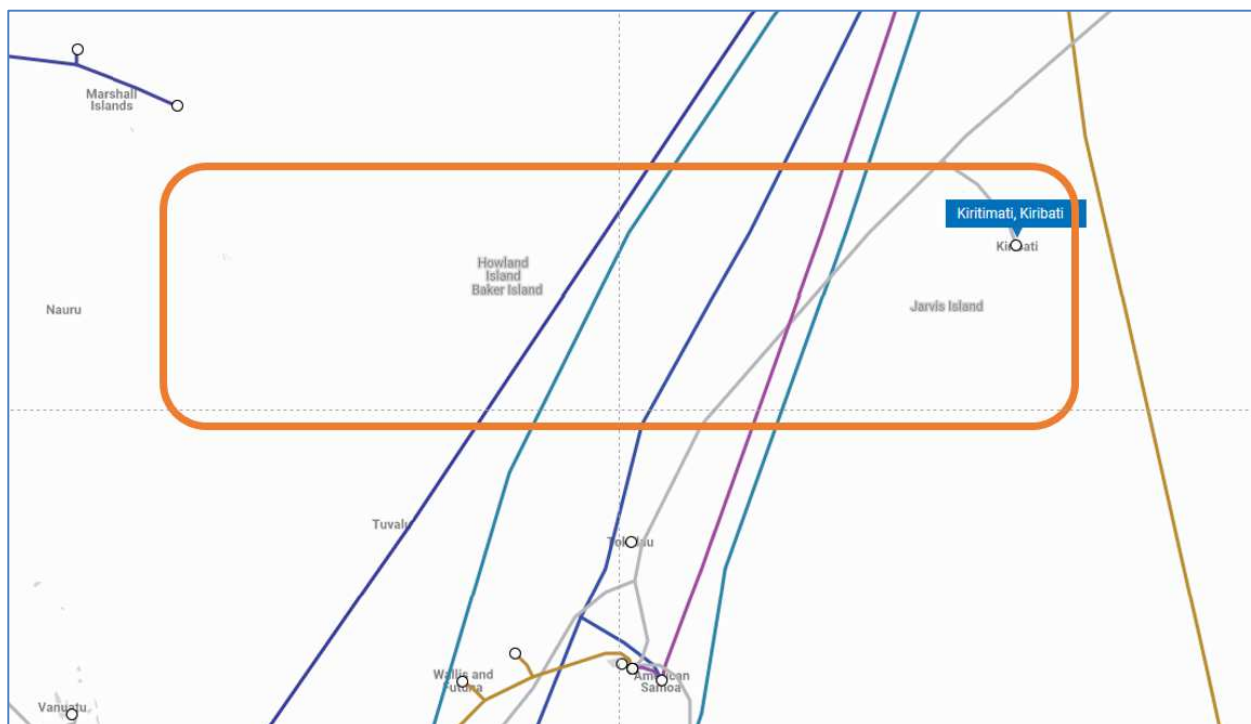
- OPT (French Polynesia) Ltd, connecting to Hawaiian Telecom and CenturyLink Communications across the Honotua cable
- Viti Ltd, connected through to Hawaiian Telecom across the Honotua cable, as well as to OPT locally within French Polynesia.

4.4.3. Latency Measurements

Providers – French Polynesia	Latency (round-trip – milliseconds)			
	Sydney	New Zealand	Singapore	USA
OPT (French Polynesia)	240	265	275	99
Viti Ltd	234	273	244	96

Country Detailed Review – Southern Zone

4.5. Kiribati (.ki)



Kiribati is not currently connected to an international cable, however one new cable is under construction.

The Southern Cross NEXT cable (RFS Q1 2022) will connect into Kiritimati through a 377km one-fibre-pair branch cable owned by Bwebwerikinet Limited (owned by the Government of Kiribati)¹¹ funded by the Asian Development Bank¹², as a branch from the main trunk cable between New Zealand and USA. Other branch cables will connect into Fiji, Samoa, Tokelau and Australia, however the Kiribati branch-cable will be on a dedicated wavelength and unable to connect directly to these intermediate locations. On SX-NEXT, Kiritimati will be able to communicate directly with New Zealand and Los Angeles, USA.

¹¹ Telegeography, Cable Compendium 11 Oct 2019, online at

<https://www.telegeography.com/products/commsupdate/articles/2019/10/11/cable-compendium-a-guide-to-the-weeks-submarine-and-terrestrial-development/>

¹² Asian Development Bank, Improving Internet Connectivity for Micronesia Project Manual, online at

<https://www.adb.org/sites/default/files/project-documents/50348/50348-001-pam-en.pdf>

Country Detailed Review – Southern Zone

4.5.1. International Cable Connectivity

Cable Name (RFS)	Owner	Destinations	Capacity	Latency
Southern Cross NEXT (under construction RFS 2022)	<i>Southern Cross Cable Consortium.</i>	<i>Los Angeles, USA</i>	<i>100 Gbps</i>	<i>59</i>
	<i>Kiritimati Branch: Kiribati Govt</i>	<i>Takapuna, New Zealand</i>	<i>100 Gbps</i>	<i>67</i>

4.5.2. Major International Providers

Kiribati communications are operated by the Government-owned Telecom Services Kiribati Limited (TSKL).

Much of Kiribati's Internet infrastructure is hosted off-island – the website infrastructure for the Kiribati Government (Communications Commission www.cck.ki) is hosted in USA, as is the website for Ministry of Information Communication Transport & Tourism Development. The nameservers, whois server information, '.ki' administration and all MX records are hosted outside Kiribati.

4.5.3. Latency Measurements

Latency measurements have not been able to be made to date, as we have been unable to find a fixed IP address that is hosted within Kiribati. With Kiribati connected solely by satellite, there are no cable latencies that can be measured.

4.6. New Caledonia (.nc)



Country Detailed Review – Southern Zone

New Caledonia is connected internationally to a single cable – Gondwana-1, which connects to a single destination - Sydney, Australia.

A new cable has been proposed by OPT-NC, named Gondwana-2, which will connect to Fiji, however construction has not commenced yet as of the date of this report.

In addition, the Hawaiki cable has installed a Branching Unit offshore New Caledonia, which is currently unused. If this BU is activated and a short cable constructed between the BU and a New Caledonia landing point, New Caledonia would be connected to the Hawaiki cable, and through that cable to New Zealand and Hawaii.

4.6.1. International Cable Connectivity

Cable Name (RFS)	Owner	Destinations	Capacity	Latency
Gondwana-1 (2008)	OPT-NC	Sydney, Australia	320 Gbps (32 Gbps used ¹³)	30ms

4.6.2. Major International Providers

New Caledonia has one major international connectivity provider – OPT (Office of Post and Telecoms), using the Gondwana-1 cable, with O3b satellite service as backup.

OPT connects upstream through Telstra Global (AS4637) and SpeedCast International (AS38456) in Sydney.

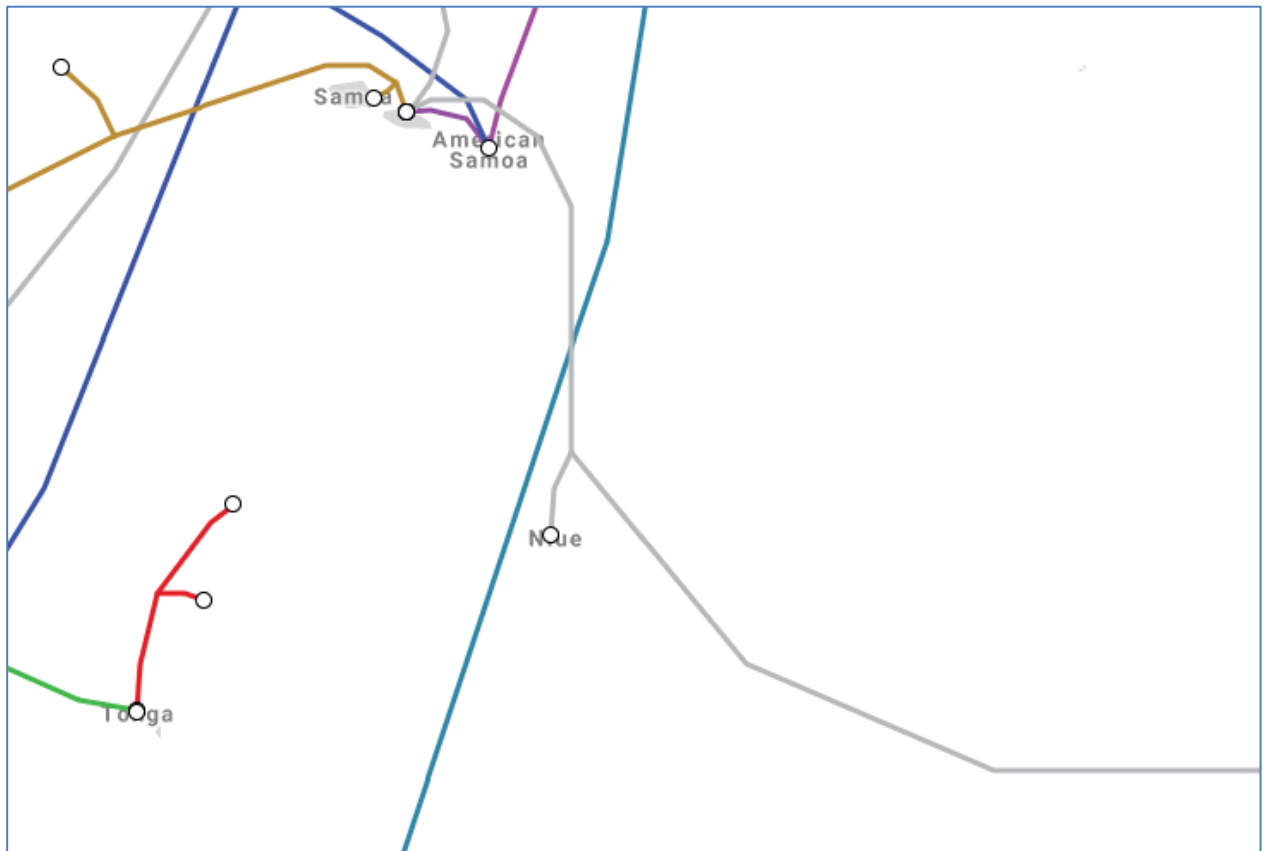
4.6.3. Latency Measurements

Providers – New Caledonia	Latency (round-trip – milliseconds)			
	Sydney	New Zealand	Singapore	USA
OPT (New Caledonia)	27	48	117	174

¹³ Fintel secures landing of GONDWANA-2, online at <http://www.fintel.com.fj/pages.cfm/company/news/to-make-caledonian-internet-safer-second-submarine-cable-rescue-gondwana-1-develop-an-international-access-offer.html>, viewed 9/9/2019

Country Detailed Review – Southern Zone

4.7. Niue (.nu)



Niue is not currently connected to an international cable, however one new cable is under construction.

The Manatua cable (RFS Q2 2020) will connect Niue as a branch on a trunk cable between French Polynesia and Samoa, with another branch cable connecting to the Cook Islands. Manatua cable has an initial design capacity 100 Gps to Niue, and an ultimate capacity of 10 Tbps (depending on detailed fibre topology).

Manatua is described as a 2/3 pair main trunk system between French Polynesia and Samoa – the Niue spur will connect to Samoa and Tahiti, French Polynesia, and may not be able to connect directly with Cook Islands.

Country Detailed Review – Southern Zone

4.7.1. International Cable Connectivity

Cable Name (RFS)	Owner	Destinations	Capacity	Latency
Manatua (under construction RFS 2020)	Manatua Cable Consortium: Avaroa Cable Ltd (.ck)	Apia, Samoa	100 Gbps	6
	Nuie Telecom (.nu)	Cook Islands	100 Gbps	14
	Samoa Submarine Cable Co (.sm) OPT (.pf)	French Polynesia	100 Gbps	16

4.7.2. Major International Providers

Niue has two primary providers of international Internet connectivity.

Rocket Systems provides connectivity through the Speedcast satellite network.

Telecom Niue provides connectivity through Spark New Zealand's Global Gateway satellite service.

On-island infrastructure for the gov.nu domain, including the government's email gateway, is connected directly through a satellite service from Spark New Zealand's Global Gateway service, using an IP address belonging to Spark New Zealand.

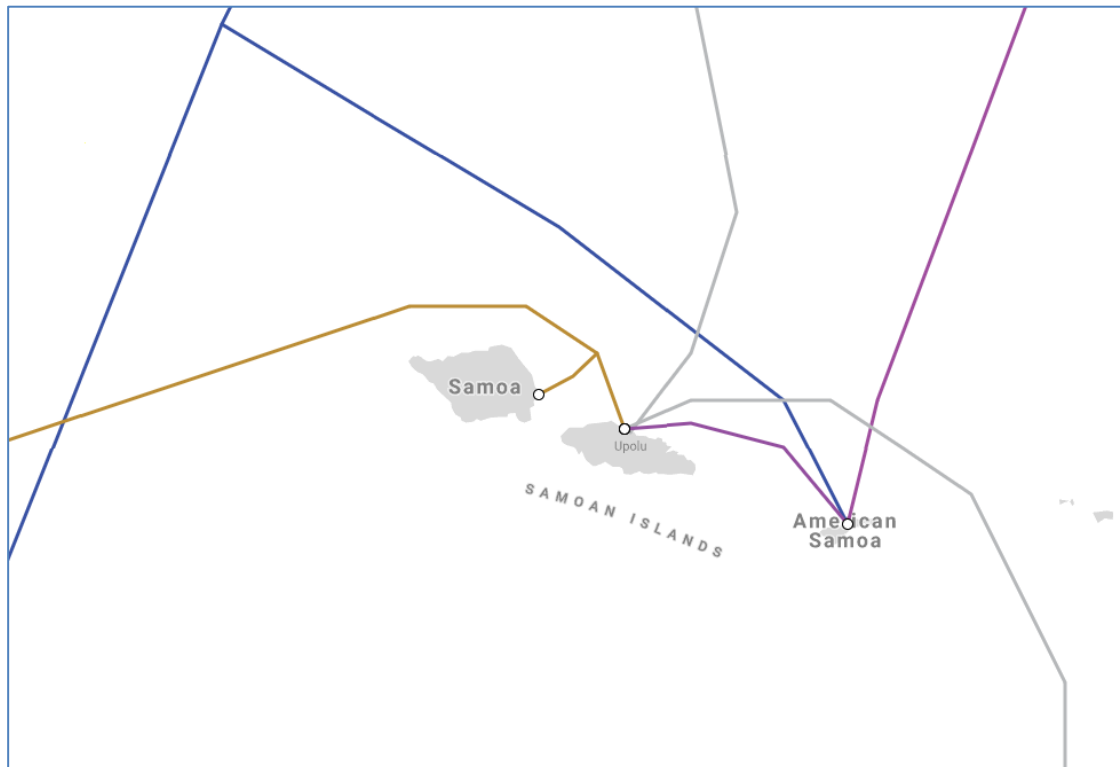
Much of Niue's Internet web content is hosted off-island – the website infrastructure for the Niue Government (www.gov.nu) and Office of the Premier (<https://niuepremierofficial.com/>) are hosted in Australia, while the infrastructure for the main private Internet Service Provider (Rocket Systems, which acquired Internet Niue) is hosted in New Zealand. The government-owned Telecom Niue's public website information (<http://telecomniue.com>) is hosted in Sweden.

4.7.3. Latency Measurements

Providers – Niue	Latency (round-trip – milliseconds)			
	Sydney	New Zealand	Singapore	USA
(Satellite)	545	571	636	651

Country Detailed Review – Southern Zone

4.8. Samoa (.ws)



Samoa is currently connected by two separate intra-Pacific cables to other Pacific island nations, with another intra-Pacific cable (Manatua) due to be completed in mid-2020, and a major trans-Pacific cable (Southern Cross NEXT) due to be connected in 2022.

The **Samoa-American Samoa cable (SAS)** was commissioned in 2009 and is owned by ASH Cable LLC - 66% owned by Fiji's Amalgamated Telecommunications Holdings Limited (ATH), and 33% owned by the Government of American Samoa. SAS links Apia, Samoa with neighbouring American Samoa, and in American Samoa can link to the ASH and Hawaiki cables. SAS was recently upgraded to 100 Gbps active, with maximum design capacity anticipated to be 800 Gbps¹⁴.

The **TUI-Samoa cable** links Samoa (two locations), Wallis and Futuna islands (two locations) and Fiji (two locations), and was commissioned and became Ready For Service in early 2018. TUI-Samoa is a single-fibre-pair cable yielding up to 8 Tbps in 80 x 100 Gbps channels, and is owned and operated by the Samoa Submarine Cable Company. In Fiji, TUI-Samoa enables interconnection with the Southern Cross cable system.

¹⁴ ASH Cable Company, 2018 – "Successful Completion of SAS Cable Upgrade", 22-Jan-2018 Media Release

Country Detailed Review – Southern Zone

The **Manatua** cable (RFS Q2 2020) will connect Samoa to French Polynesia, with a branch cable to Niue and another branch cable connecting to the Cook Islands. Manatua cable has an initial design capacity 100 Gbps, and an ultimate capacity of 10 Tbps (depending on detailed fibre topology).

Manatua is described as a 2/3 pair main trunk system between French Polynesia and Samoa – it is currently not public knowledge as to the architecture of the fibre pairs within the cable, and whether the countries on the branch cables – Niue and Cook Islands – will be able to communicate with each other as well as each end.

The **Southern Cross NEXT cable** (RFS Q1 2022) will connect a one-fibre-pair branch cable into Apia, Samoa as a branch from the main trunk cable between Australia, New Zealand and the USA near Los Angeles. Other branch cables will connect into Fiji, Kiribati, Tokelau and Australia, however the Samoan branch-cable will be on a dedicated wavelength and unable to connect directly to the intermediate locations. On SX-NEXT, Samoa will be able to communicate directly with New Zealand and Los Angeles, USA.

4.8.1. International Cable Connectivity

Cable Name (RFS)	Owner	Destinations	Capacity	Latency
Samoa-American Samoa (SAS) cable	ASH Cable LLC	Pago Pago, American Samoa	100 Gbps	5
TUI-Samoa Cable	Samoa Submarine Cable Company	Wallis & Futuna Islands	100 Gbps	8
		Suva, Fiji	100 Gbps	15
Manatua (under construction RFS 2020)	Manatua Cable Consortium: Avaroa Cable Ltd (.ck) Nuie Telecom (.nu) Samoa Submarine Cable Co (.sm) OPT (.pf)	Alofi, Niue	100 Gbps	6
		Cook Islands	100 Gbps	24
		French Polynesia	100 Gbps	34
Southern Cross NEXT (under construction RFS 2022)	Southern Cross Cable Consortium.	Takapuna, New Zealand	100 Gbps	42
	Samoa Branch: Samoa Submarine Cable Company	Los Angeles, USA	100 Gbps	83

4.8.2. Major International Providers

Samoa has three primary providers of international connectivity using the subsea cables.

Country Detailed Review – Southern Zone

Bluesky Samoa (Amalgamated Telecom Holdings (ATH)/American Samoa Telecom LLC (AST)) provides capacity solely from mainland USA. The exact path is uncertain, as the measured latency is significantly longer (143 milliseconds) than any direct cable capacity even via Fiji. While the Southern Cross cable connects to multiple locations including Australia, New Zealand and Hawaii, Bluesky does not use these entry points - all traffic from across the globe – including from Australia, New Zealand and Hawaii – must funnel into a datacentre in San Jose, California before being carried to Bluesky’s network across a link with round-trip-time minimum 143 milliseconds.

CSL also provides access solely on a single path direct from mainland USA via Hawaii. All traffic from across the globe – including from Australia, New Zealand and Hawaii – must funnel into a datacentre in San Francisco, California before being carried to CSL’s network across a link with round-trip-time minimum 147 milliseconds.

Digicell Samoa provides connectivity using the TUI-Samoa cable to Fiji, and then the Southern Cross cable system from Fiji to Sydney, Australia. All traffic from across the globe – including from the USA, New Zealand and Asia – is routed to Sydney before being carried to Digicell’s network across a link with round-trip-time minimum 49 milliseconds from Sydney.

The Samoan Government website at www.samoagovt.ws is hosted by a third-party web hosting provider in Boston, MA, USA.

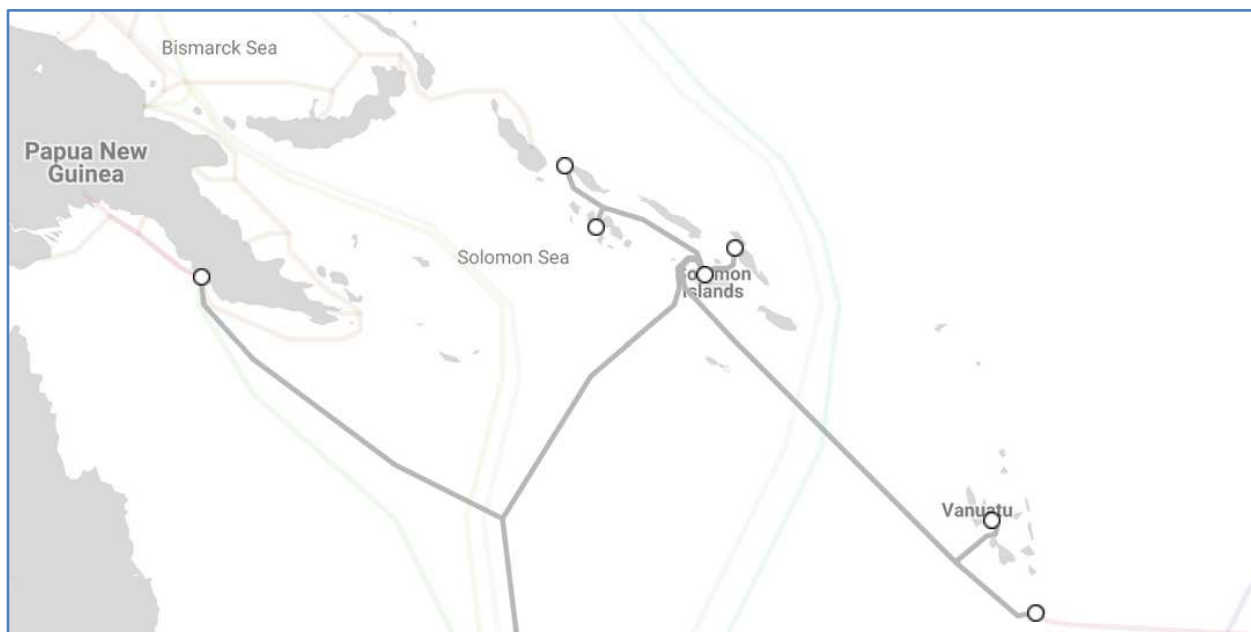
The Samoan Top Level Domain registry website for '.ws' appears to be hosted in Los Angeles, USA.

4.8.3. Latency Measurements

Providers – Samoa	Latency (round-trip – milliseconds)			
	Sydney	New Zealand	Singapore	USA
BlueSky Samoa	280	306	301	143
CSL	284	310	307	147
Digicell Samoa	49	77	140	204

Country Detailed Review – Southern Zone

4.9. Solomon Islands (.sb)



Solomon Islands is not currently connected to an international cable, however two new cables are under construction.

The ICN2 (RFS Q4 2019) will connect Solomon Islands to Vanuatu, with initial design capacity of 200 Gbps.

The Coral Sea Cable System (RFS Q1 2020) will connect the Solomon Islands to Sydney, Australia. A second fibre-pair will connect Port Moresby to Sydney.

4.9.1. International Connectivity

Cable Name (RFS)	Owner	Destinations	Capacity	Latency
ICN2 (proposed 2019)	Interchange Ltd (VU)	Port Vila & Luganville, Vanuatu	200 Gbps	10
Coral Sea Cable System (proposed 2020)	Solomon Islands Submarine Cable Company (SB)	Sydney, Australia	200 Gbps	24

4.9.2. Major International Providers

Solomon Islands has one major international connectivity provider – Solomon Telekom.

In addition, SATSOL and BEMOBILE provide mobile telephone services via Satellite (Speedcast)

Solomon Telekom currently connects upstream through 03b Satellite (AS60725) in Hawaii.

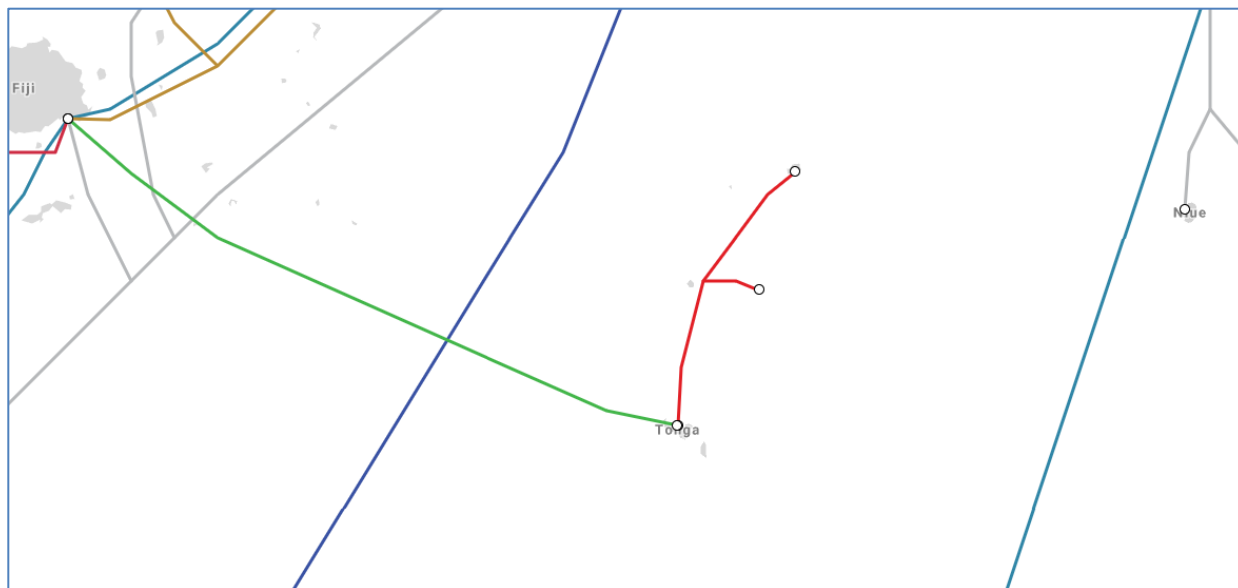
Country Detailed Review – Southern Zone

4.9.3. Latency Measurements

Providers – Solomon Islands	Latency (round-trip – milliseconds)			
	Sydney	New Zealand	Singapore	USA
Solomon Telekom	207	344	354	180

Country Detailed Review – Southern Zone

4.10. Tonga (.to)



Tonga is currently connected by the Tonga international cable to Fiji. A domestic cable extends the connectivity to other Tongan islands.

The **Tonga cable** links Tonga with Fiji, and was established in 2013 and is jointly owned by Government of Tonga (66.6%), Tonga Communications Corporation and Digicel Tonga (16.7% each).

4.10.1. International Cable Connectivity

Cable Name (RFS)	Owner	Destinations	Capacity	Latency
Tonga Cable	Tonga Cable Limited	Suva, Fiji	??	9

4.10.2. Major International Providers

Tonga has three providers of international connectivity using the Tonga subsea cable.

Tonga Cable Limited connects to the USA with Cogent Communications, which uses the Southern Cross cable system, and then on the Tonga cable. Tonga Cable Limited also connects to Sydney using Vocus Communications.

Tonga Communications connects through Fiji International Telecoms Limited, which then connects through Cogent as well. Cogent does not participate in any local interconnections of peering, so all global traffic must funnel into a datacentre in USA before being carried to Tonga.

Digicel Tonga connects through the Tonga cable to Digicel Fiji in Fiji, and onwards using Digicel Fiji's Internet connections.

Country Detailed Review – Southern Zone

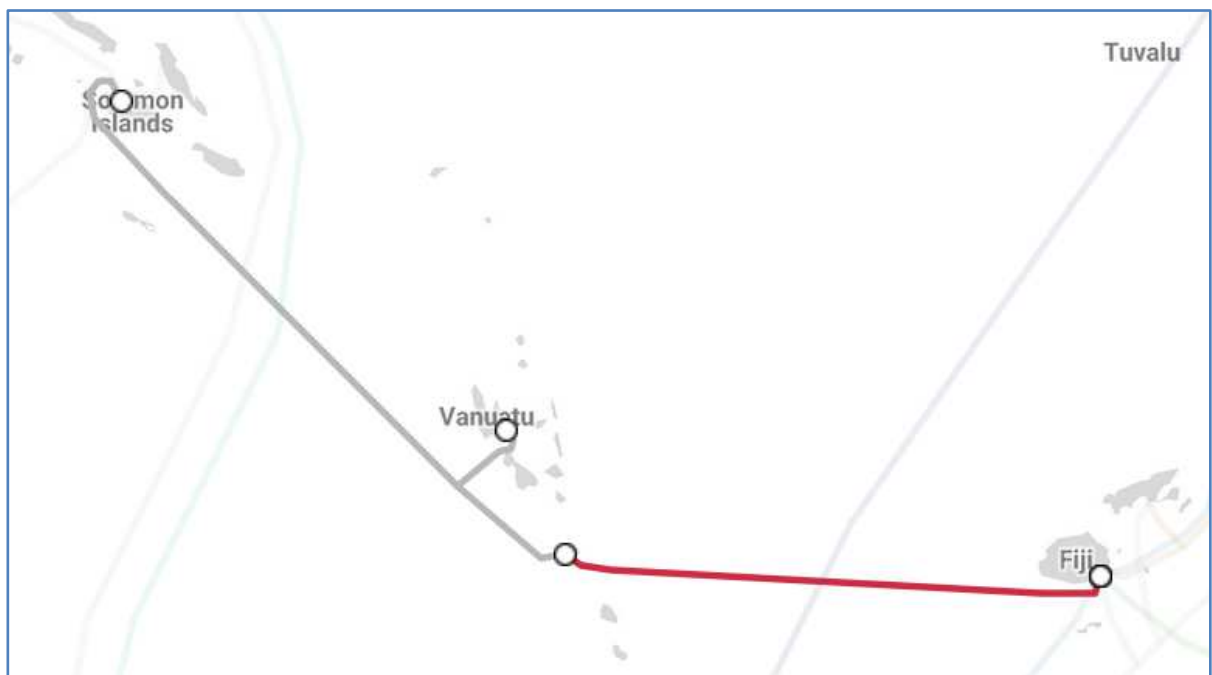
Many of the Tongan Government websites (www.pmo.gov.to, mic.gov.to, and www.thekingdomoftonga.com) are hosted at third-party hosting providers in the USA and Europe, while others have some form of infrastructure, such as mail servers, hosted locally.

The Tongan Top Level Domain registry website www.tonic.to appears to be hosted in San Francisco, USA.

4.10.3. Latency Measurements

Provider - Tonga	Latency (round-trip – milliseconds)			
	Sydney	New Zealand	Singapore	USA
Tonga Communications Corp	161	186	223	167
Tonga Cable Limited	44	69	223	198
Digicel Tonga	45	69	136	192

4.11. Vanuatu (.vu)



Vanuatu is currently connected to Fiji via the ICN1 cable.

The **InterChange Cable Network-1 (ICN1)** cable links Fiji with Vanuatu, commissioned in 2014. ICN1 is owned and operated by Interchange Limited based in Vanuatu. The anticipated full capacity is 1280 Gbps.

Country Detailed Review – Southern Zone

A second cable under construction ICN2 cable (RFS Q4 2019) will connect Vanuatu to the Solomon Islands, with initial design capacity of 200 Gbps.

The Vanuatu Internet Exchange (VIX) was established in 2013, and in addition to the network access providers is also the location of a Google cache server and two root DNS servers¹⁵. Its domain name vix.vu no longer resolves.

4.11.1. International Cable Connectivity

Cable Name (RFS)	Owner	Destinations	Capacity	Latency
ICN1	Interchange Ltd (VU)	Suva, Fiji	1280 Gbps	13
ICN2 (proposed 2019)	Interchange Ltd (VU)	Luganville, Vanuatu	200 Gbps	10

4.11.2. Major International Providers

Vanuatu has two international connectivity providers:

- Telecom Vanuatu, connecting to Vodafone Fiji across the ICN1 cable
- Interchange Ltd, connected through to Sydney Australia via the ICN1 cable to Fiji and then Southern Cross Cable to Australia.

4.11.3. Latency Measurements

Providers – Vanuatu	Latency (round-trip – milliseconds)			
	Sydney	New Zealand	Singapore	USA
Telecom Vanuatu	50	77	176	144
Interchange Ltd	49	75	140	246

4.11.4. Tonga IXP

Tonga is in the process of establishing a national IXP, commencing planning in 2018, for local interconnectivity amongst Tongan ISPs.

¹⁵ Webston, J (2015), "Vanuatu Internet Exchange (VIX): a success story", APNIC Blog post, online at <https://blog.apnic.net/2015/01/23/vanuatu-internet-exchange-vix/>

Submarine Optical Fibre Routing Considerations

5. Submarine Optical Fibre Routing Considerations

Geographic cable maps may not provide a good indication of the connectivity options available for a cable. The presence of Branching Units ("BUs"), and spur-cables may indicate fewer connectivity options than a geographic map may suggest.

Optical fibres in a submarine cable are deployed in pairs – one fibre 'transmit', one fibre 'receive', and there are typically only a small number of fibres – from a single pair up to six pairs (two fibres up to 12 fibres).

5.1. Branching Units

To provide flexibility, some cables are deployed with Branching Units ("BUs") where fibre paths can be split out or joined together, forming a 'T-piece' arrangement. Usually a subset of fibre pairs is redirected within a BU, with some fibres directed in one direction and the remaining fibres routed in another direction. This enables a small amount of capacity to be re-directed to a location that is anticipated to not require a significant fraction of the cable capacity, while other capacity can bypass that location, including staying outside international jurisdiction. Bypassing the branching cable removes the latency that would otherwise be caused by traversing the branch cable twice, and also eliminates the costs of two back-to-back sets of optical equipment at the branch cable-station.

In recent cables, the development of smaller optical gratings and wavelength-dependent processors has enabled BUs to be able to switch not only whole fibres, but also portions of the optical spectrum within a single fibre-pair, enabling individual optical paths (also known as 'wavelengths') to be directed to the branch cable while other wavelengths in the same fibre-pair pass through the BU without being bypassed.

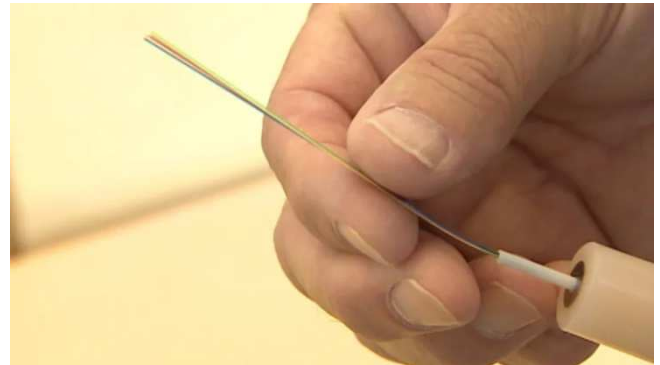


Figure 13 - Cable showing optical fibres

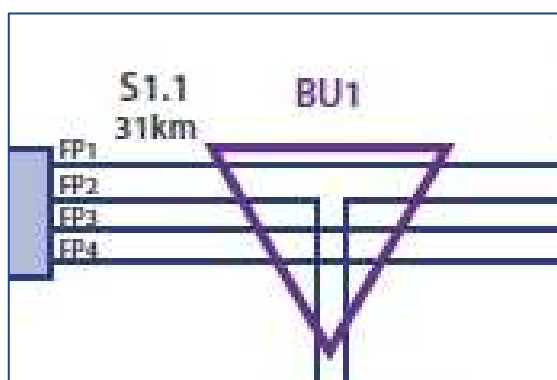


Figure 14 - Branching unit, and BU diagram

Submarine Optical Fibre Routing Considerations

Figure 14 shows a branching unit being deployed, and a representation of a branching unit in a cable diagram. Note in the diagram, each line represents a pair of fibres - the main cable consists of four fibre-pairs, or 8 individual fibre strands.

Only one fibre-pair (FP2) is diverted from the main cable to the branching destination to the south. The other three fibre-pairs pass straight through the BU without being diverted. The branching spur to the south consists of a two-pair cable.

Importantly, the location connected to the branch fibre can only communicate with endpoints directly connected to FP2. It cannot communicate with any endpoint to which the other three fibre-pairs are connected, as those fibres do not land at the landing station at the end of the branch cable.

These considerations are important to understand in the context of any cable system that consists of spur-cables connected using Branching Units to a main cable, as illustrated by the Hawaiki cable and the under-construction Southern Cross NEXT cable system.

5.2. Hawaiki Cable System example

5.2.1. Geographic view



Figure 15 - Hawaiki cable geographic map

Submarine Optical Fibre Routing Considerations

The Hawaiki cable system is a 15,000 km telecommunication cable connecting Australia, New Zealand, American Samoa, Hawaii and continental United States, with other 'stubs' ready to connect to Fiji, Tonga and New Caledonia.

5.2.2. *Straight Line Diagram view*

The 'Straight Line Diagram' of a subsea cable details exactly how many fibre-pairs are built into the cable, and which path each individual optical fibre-pair takes. It shows the characteristics of each branching unit, including which fibre-pairs go in which direction.

The Straight Line Diagram for the Hawaiki cable illustrates some restrictions that are not evident from the geographic map:

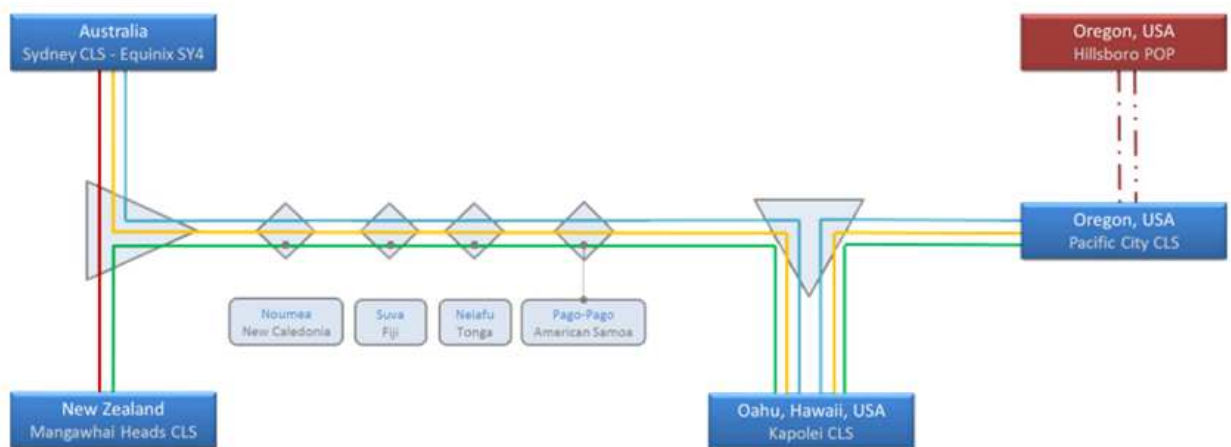


Figure 16 - Hawaiki cable - Straight Line Diagram

The Straight Line Diagram shows there are three fibre-pairs within the main cable – two fibre-pairs between Australia and Hawaii (blue and yellow on the diagram), one fibre-pair between Australia and New Zealand, and one fibre-pair between New Zealand and Hawaii. Every fibre-pair from Australia/New Zealand towards the USA terminates in Hawaii, and signals are regenerated on a matching set of fibre-pairs towards mainland USA from Hawaii.

Importantly, the diagram shows that each of the spurs to the Pacific island nations of New Caledonia, Fiji, Tonga and American Samoa are all connected to a single fibre-pair – the 'green' fibre-pair between Hawaii and New Zealand in the diagram above.

This indicates that providers in American Samoa (and each of the other spur-cables if connected) cannot connect directly to Australia – all connections to/from American Samoa must pass through New Zealand, and any traffic between American Samoa and Australia will have additional latency from traversing the cable between New Zealand and the large branching unit twice. For the lowest latency and best performance traffic, these Pacific Island nations should connect to upstream networks and peering exchanges in New Zealand, rather than to suppliers in Australia.

Submarine Optical Fibre Routing Considerations

5.2.3. Wavelength map view

Drilling down into more detail, within a single fibre-pair there may be up to 100 optical channels or 'wavelengths' active, using light signals at different frequencies to provide parallel separated circuits in much the same way that a radio or television spectrum enables multiple stations to transmit their signals in parallel.

Many Branching Units are installed with optical filters that can redirect individual wavelength channels towards a branch fibre, rather than all the wavelength of the entire optical fibre.

Many of the spur-cables in the Pacific region redirect just a single wavelength channel on the spur cable, typically operating at 100 Gbps capacity.

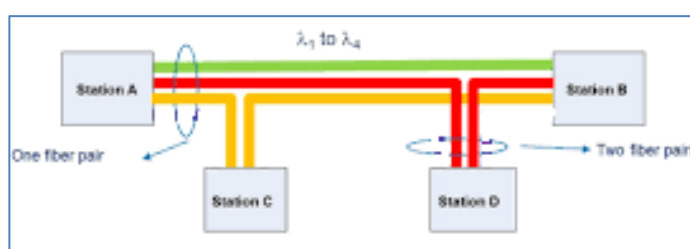


Figure 17 - Notional wavelength map to two spur cables (adapted from Nyman, 2015)

The typical architecture for the wavelength map is to allocate a different dedicated wavelength to each spur, illustrated by the red and yellow lines in Figure 17¹⁶. By using different wavelengths within the same fibre-pair, each spur destination can access the full capacity of their wavelength channel without interference from any other spur station. In addition, a problem at a spur landing station which interrupts the signal through the cable will not affect any other spur, as the other spur's wavelengths pass directly through the BU without being directed to each spur along the chain.

The consequence of this architecture is that adjacent spur cables cannot communicate with each other – only with the stations at the ends of the fibres. In the diagram above, Station C and Station D can only communicate with A and B, and not each other.

On the Hawaiki cable, the four island nations on spur cables can only communicate directly with New Zealand and Hawaii. When New Caledonia is connected¹⁷, it will also only be able to communicate with New Zealand and Hawaii, but not to the existing spur-cable to American Samoa.

¹⁶ Nyman, Bruce 2015, "Flexibility in Submarine Fiber Optic Networks [Invited]," J. Opt. Commun. Netw. 7, A553-A557

¹⁷ Bannerman, Natalie, 2019, "New Caledonia to build branch cable to Hawaiki", <https://www.capacitymedia.com/articles/3824587/new-caledonia-to-build-branch-cable-to-hawaiki>

Submarine Optical Fibre Routing Considerations

This inability to communicate with adjacent spur cables is relevant to the consideration of which location to site a Pacific Islands IX – locating at a spur-cable location will prevent any other nation on a spur of the same cable from communicating on the lowest-latency path.

5.3. Southern Cross NEXT cable



Figure 18 - SX-NEXT cable path, RFS 2022 (image: Capacity Media)

Submarine Optical Fibre Routing Considerations

Southern Cross NEXT is a new trans-Pacific cable commencing build in 2019, and projected to be completed in 2022.

Unlike the original Southern Cross cable system, Southern Cross NEXT will make use of a significant number of branching units to provide connectivity to Pacific islands of Fiji, Kiribati, Samoa and Tokelau.

The Southern Cross consortium have not published public Straight Line Diagrams, however we understand from industry sources that the architecture is similar to Hawaiki in the following respects:

- 1) The four Pacific Island branching units connect spur cables (1-fibre-pair each) to the same main trunk fibre-pair
- 2) That fibre-pair connects to New Zealand in the southwards direction, and to mainland USA near Los Angeles in the northwards direction. It does not connect directly to Australia, and so traffic from any of the Pacific island nations to/from Australia will need to traverse through New Zealand first.
- 3) Each of the four Pacific island spur cables will redirect a dedicated wavelength optical channel, different from the wavelength channels allocated to the other spur cables. The Pacific island nations will not be able to communicate directly between each other, as a connection between them will instead have to traverse through New Zealand, switch wavelength channel, and then come back along the cable, significantly increasing the latency between Pacific island countries.

For the purposes of this study and determining the optimum location of a Pacific IX, SX-NEXT is treated as four separate cables, each connecting a Pacific island nation to New Zealand in one direction and to mainland USA in the other direction.

6. Internet (World Wide Web) Latency Test Methodology

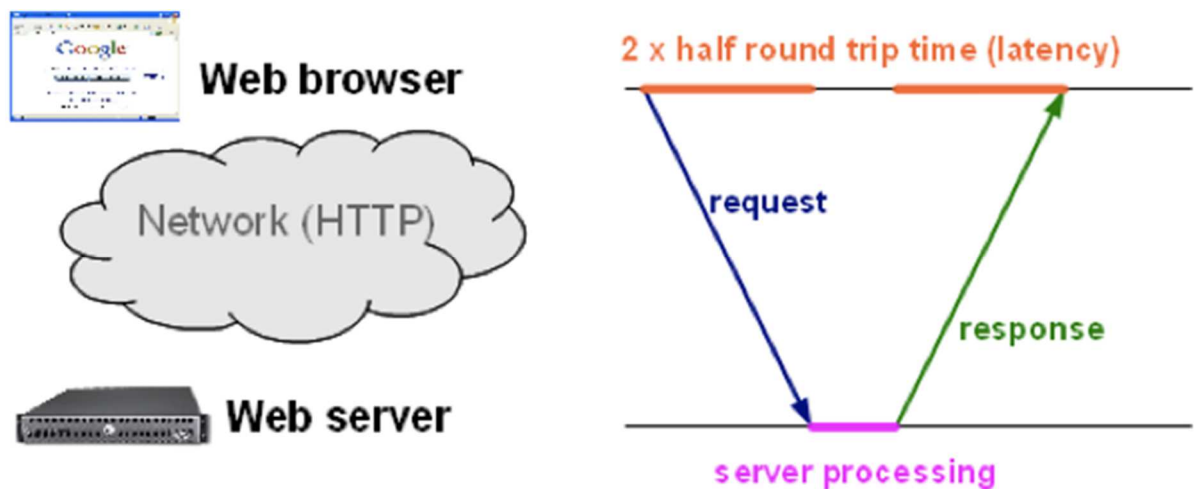
6.1. Latency and Round-Trip Delay

Internet “latency” is a measure of the time delay that Internet content experiences while traversing the end-to-end path of the global Internet from source to destination.

In most cases Internet traffic travels at the speed of light, but the distances it travels across the globe are so vast that this still incurs a measurable time delay – within an optical fibre cable on the seabed crossing the Pacific Ocean requires around 70 milliseconds to cross from New Zealand to the USA, and another 70 milliseconds to travel back, for a round-trip-time of 140 milliseconds.

Using satellite services, the round-trip delay is even higher, due to the requirements of the signal to travel the long distance up to an orbiting satellite and back again – satellite time delays of 300ms to 500ms are usual.

Strictly speaking, the word ‘latency’ usually refers to the delay in one direction, from ‘source’ to ‘destination’. However, the latency is usually measured by sending test traffic out and waiting for it to return, mimicking the usual pattern of Internet access, sending out a request for information (by clicking on a website link for example) and then later receiving the result. This gives the ‘round-trip delay’ or ‘round-trip’ latency, since it incorporates the total delay for information to be sent out to the destination and then come back again.



(from Daspet, “All you should know about your first enemy: Latency”,
<https://calendar.perfplanet.com/2010/know-your-enemy-latency/>)

Figure 19 Latency and round-trip delay

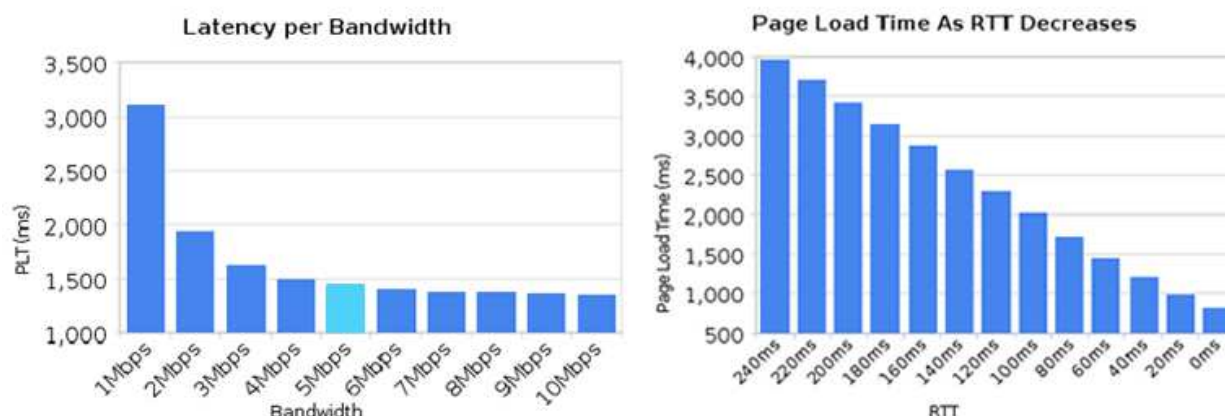
Internet (World Wide Web) Latency Test Methodology

Latency is a key indicator of Internet performance – the lower the latency of a path, the faster information will return and the higher performance will result. Websites in particular often require many hundreds and thousands of requests and responses for information, images, formatting statements, icons and pictures that build up to the picture displayed on the screen. The lower the latency on the whole path between requestor and server, and back again, the faster the content will load and the webpage content will appear to the user sooner.

Minimising latency and round-trip-delay is a major method of improving Internet services and performance.

6.2. Latency (not link speed) is the critical component of website page-load performance

Research performed at Google in 2011¹⁸ showed that the nature of the HTTP protocol and TCP/IP shows that increasing capacity of an end-user's broadband link beyond around 5 Mbps achieves little incremental performance benefit. HTTP traffic tends to make use of short and bursty connections, and is mostly idle while awaiting for responses from the far-end server. An increase from 5Mbps to 10Mbps results in only a 5% improvement in page load times. Extra capacity (higher speed) links provide benefits when there are multiple users and devices using the link, but once the link is fast enough to carry the desired load without congestion, there is little performance benefit achieved from even more speed.



(Source: Grigorik 2012)

Figure 20 - Latency improves page loads more than bandwidth above ~ 5 Mbps

Reducing Latency, however, has a dramatic effect – in the examples tested, every 20 milliseconds shaved off the round-trip time resulted in a linear improvement in page load times.

¹⁸ 2010, Belshe, "More Bandwidth Doesn't Matter (much)", 08/Apr/2010, online at <https://docs.google.com/a/chromium.org/viewer?a=v&pid=sites&srcid=Y2hyb21pdW0ub3JnfGRldnxneDoxMzcyOWI1N2I4YzI3NzE2>

Internet (World Wide Web) Latency Test Methodology

As reported by Ilya Grigorik¹⁹, "when it comes to your web browsing experience, it turns out that latency, not bandwidth, is likely the constraining factor today."

The effect is magnified, because the retrieval of a typical element of website content may require multiple RTT traversals of the link, to perform the following tasks:

- 1) DNS lookup to translate name to IP address
- 2) TCP connection to establish a connection to the server
- 3) TLS encryption negotiation to establish an encrypted secure connection
- 4) Send web query, and receive the response.

As illustrated below, up to five RTT cycles of the link may be required to retrieve one component of a website:

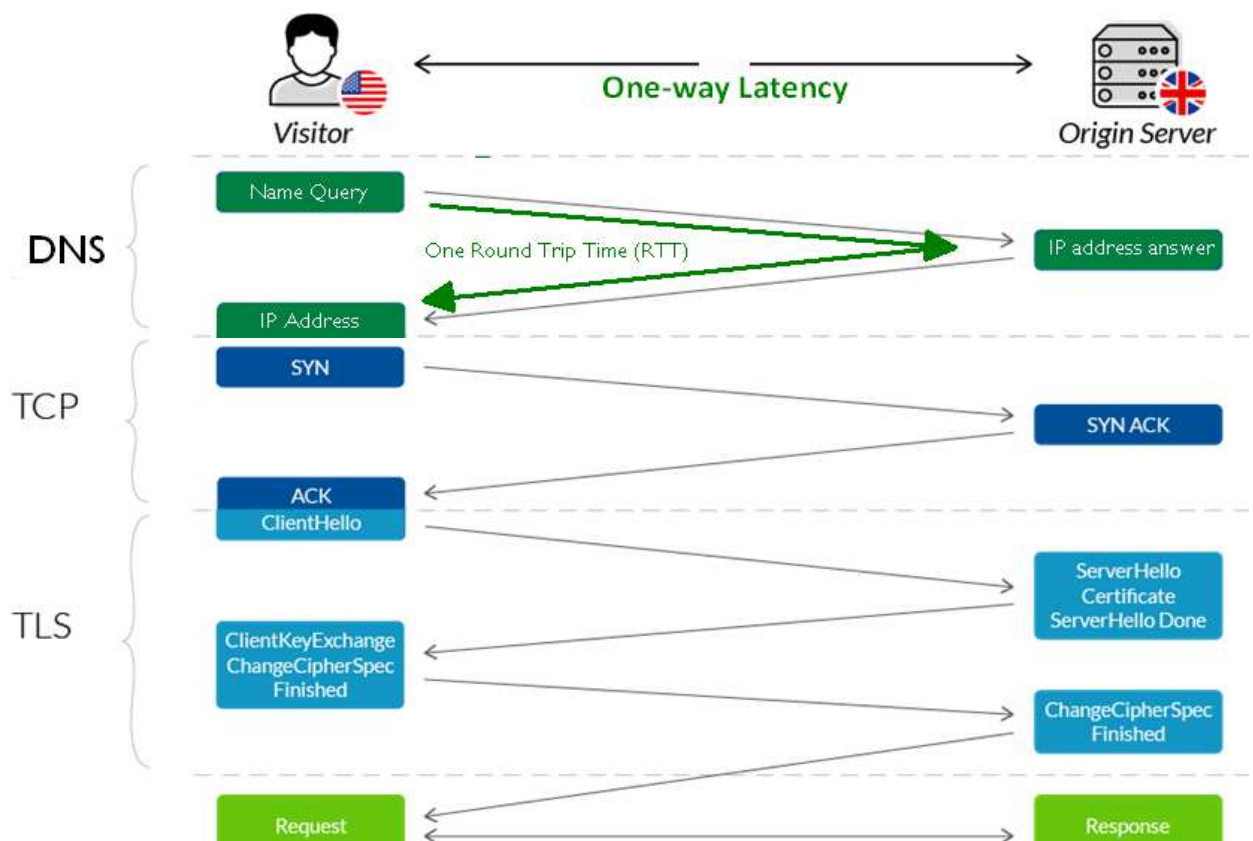


Figure 21 - One website 'element' requires many (~5) RTTs

It is evident from this that reducing the latency (or round-trip time) between request and server will have a dramatic effect on the end-to-end time for retrieving Internet content.

¹⁹ 2012, Grigorik, "Latency, The New Web Performance Bottleneck", 19/Jul/2012, online at <https://www.igvita.com/2012/07/19/latency-the-new-web-performance-bottleneck/>

Internet (World Wide Web) Latency Test Methodology

6.3. Web-page accesses require many round-trips from many sources

A typical web-page consists of many elements (pictures, formatting commands, links, headings etc) which each need to be individually retrieved across the Internet. Many - indeed most - of these elements are not retrieved from the server with the name that was requested.

Consider access to the popular accommodation website **airbnb.com.au** as an example:

Using tools built into a web-browser it is possible to see the elements loaded by the website:

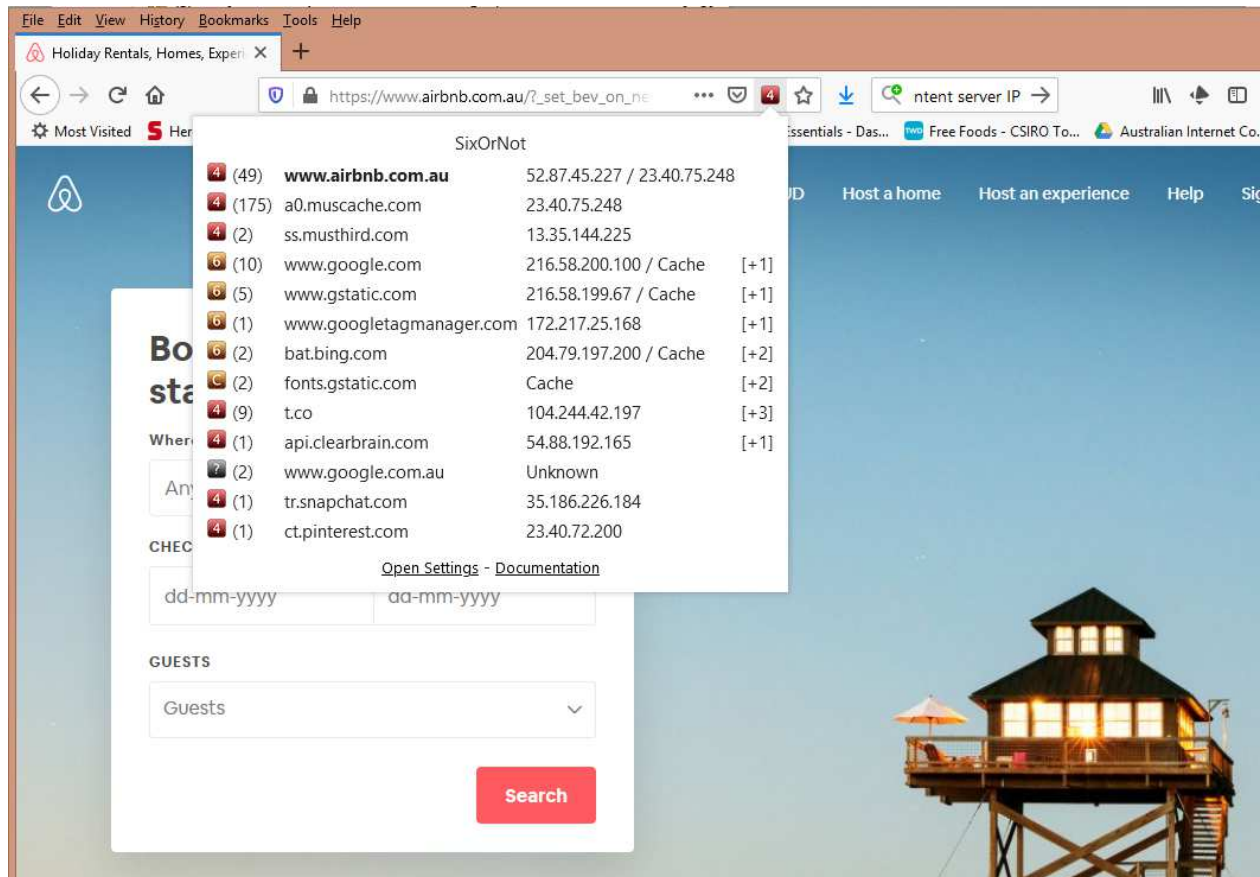


Figure 22 - List of elements retrieved for 'www.airbnb.com.au'

Note the website loads the majority of its elements from sources that are **not stored** on an www.airbnb.com.au server.

The website loads elements from many sources that may be scattered all over the global Internet:

- 49 elements from two different addresses associated with Akamai caches
- 177 elements from 'muscache' and 'musthird' servers
- 20 elements from Google servers
- 2 elements from bing.com (Microsoft servers)
- 9 elements from Twitter servers
- 1 element from 'clearbrain.com'
- 1 element from snapchat.com

Internet (World Wide Web) Latency Test Methodology

- 1 element from pinterest.com

In fact, since 'airbnb.com.au' is served by an Akamai Technologies cache, **none** of the www.airbnb.com.au website actually is downloaded from an Airbnb server, and the performance of the headline elements will be identical to every other website served from the same Akamai Technologies CDN cache.

The next diagram shows the actual round-trip delays, measured from Sydney, to each of these sources:

	SixOrNot	Latency ms	Service	Location
(49) www.airbnb.com.au	52.87.45.227 / 23.40.75.248	280 / 11	Amazon AWS / Akamai	USA / Sydney
(175) a0.muscache.com	23.40.75.248	11	Akamai	Sydney
(2) ss.musthird.com	13.35.144.225	10	Cloudfront	Sydney
(10) www.google.com	216.58.200.100 / Cache	[+1] 9	Google	Sydney
(5) www.gstatic.com	216.58.199.67 / Cache	[+1] 9	Google	Sydney
(1) www.googletagmanager.com	172.217.25.168	[+1] 9	Google	Sydney
(2) bat.bing.com	204.79.197.200 / Cache	[+2] 22	Microsoft MSN	Melbourne
(2) fonts.gstatic.com	Cache	[+2] 9	Google	Sydney
(9) t.co	104.244.42.197	[+3] 11	Twitter	Sydney
(1) api.clearbrain.com	54.88.192.165	[+1] 211	Amazon AWS	USA
(2) www.google.com.au	Unknown	11	Google	Sydney
(1) tr.snapchat.com	35.186.226.184	11	Google	Sydney
(1) ct.pinterest.com	23.40.72.200	8	Akamai	Sydney

Figure 23 - Content sources and RTTs for webpage elements

Things to note:

- 1) With one DNS lookup per service, and up to 4 RTTs for each of ~ 260 elements, retrieving this webpage and displaying it on the screen may require over 1100 RTT interactions.
- 2) The majority of elements are served from the same city as the browser, however some are served from locations over 200 milliseconds away – these are likely to affect the page-load time on the screen.
- 3) The performance of this website is entirely determined by the performance of a small number of global content servers – Google, Akamai, Cloudfront, Microsoft, Amazon AWS.

For another example, consider testing to the website for the Rarotonga International Airport, Cook Islands. - www.cookislandsairport.com.

Internet (World Wide Web) Latency Test Methodology

SixOrNot

Domain	IP Address	Latency
www.cookislandsairports.com	104.18.47.28 / 104.18.46.28	[-]
ajax.googleapis.com	2606:4700:30::6812:2f1c	[+8]
fonts.googleapis.com	2606:4700:30::6812:2e1c	[+1]
fonts.gstatic.com	2404:6800:4006:80a::200a	[+1]
www.googletagmanager.com	2404:6800:4006:802::2003 / Cache	[+1]
www.youtube.com	2404:6800:4006:802::2008	[+5]
www.statcounter.com	2404:6800:4006:804::200e / Cache	[+1]
www.google.com	104.20.3.47	[+2]
www.google-analytics.com	2404:6800:4006:808::2004 / Cache	[+2]
pagead2.googlesyndication.com	2404:6800:4006:80a::200e	[+1]
googleads.g.doubleclick.net	2404:6800:4006:80a::2002 / Cache	[+1]
adservice.google.com.au	2404:6800:4006:809::2002	[+1]
static.doubleclick.net	2404:6800:4006:805::2002	[+1]
yt3.ggpht.com	2404:6800:4006:807::2006	[+1]
adservice.google.com	2404:6800:4006:804::2001	[+1]
i.ytimg.com	2404:6800:4006:80b::2002	[+1]
www.googletagservices.com	2404:6800:4006:80b::2016	[+1]
c.statcounter.com	2404:6800:4006:808::2002	[+1]
s07.flagcounter.com	104.20.3.47	[+1]
www.gstatic.com	104.243.42.114	[+2]
www.gstatic.com	172.217.25.35	[+2]

Kia Orana & Welcome to Cook Islands Airports - Rarotonga International, Aitutaki and more

Cookislandsairports.com brings you information on Rarotonga International and Aitutaki Airports, along with all other domestic airports in the Cook Islands. This site is operated by [Air Rarotonga Limited](#), the Airline of the Cook Islands.

With today's flight arrivals and departures for Rarotonga International, we bring you up to date travellers information for all our airports including Aitutaki and our neighbouring Islands.

Rarotonga is the capital of the Cook Islands, 15 jewels dotted over 2,500,000 square kilometres of the tropical South Pacific Ocean. Served in the 1950's by T.E.A.L. Short Seaplane flying boats on the famous 'Coral Route' the Cook Islands entered the jet

Physically, the main page of this website (www.cookislandsairports.com) is actually hosted in Sydney, Australia, however it also includes many embedded elements from Google (googleapis.com, gstatic.com, youtube.com) and several user tracking sites (statcounter.com, doubleclick.net, ggphd.com, ytimg.com, flagcounter.com, openx.net).

Accessing this website from within the Cook Islands would result in the web-browser making connections to at least ten different organisations/destinations, scattered across Australia and the USA. Most (particularly the Google/Youtube hosts) are located in multiple datacentres across the globe, and would (from within the Pacific Islands) be served from the closest available point – but likely to be served from datacentres outside the Cook Islands, and result in traffic over the satellite links.

One, however (s07.flagcounter.com) appears to be only served from New York, USA and may contribute to slow loading times for this website overall.

Internet (World Wide Web) Latency Test Methodology

The Cook Islands are currently served by a satellite link, and does not yet have a submarine fibre connection, so the latency from Cook Islands to the USA (180 milliseconds) and Australia (over 300 milliseconds) is very high. If a resident of the Cook Islands was accessing this website from within the Cook Islands, all of these elements, including the 'headline' 29 elements of www.cookislandsairports.com would need to be retrieved over the satellite links, resulting in significantly slow performance and likely to be impacted during peak times by any congestion on the satellite links.

6.4. Many Internet services are not served from their public websites

When measuring the performance and latency of an Internet service, it is tempting to measure the performance and latency of the website belonging to the service – however this will often result in a completely misleading measurement.

Consider the popular video streaming service Netflix (www.netflix.com), as an example of the video content streaming services that are generating much of the traffic on modern Internet services. From a typical ISP service in Sydney, Australia -

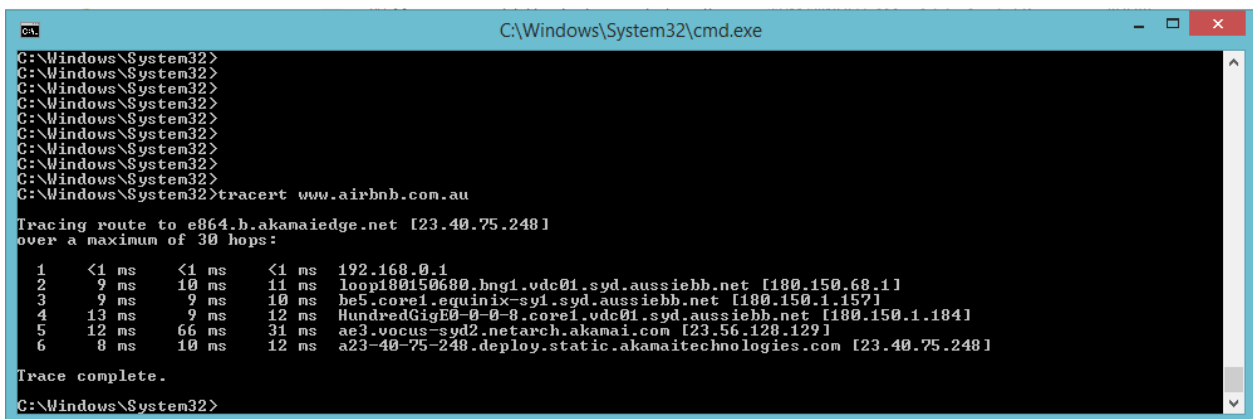
- 1) www.netflix.com is translated to www.us-west-2.prod.netflix.com, which in turn is translated to IPv4 address 52.41.20.47, which is hosted in San Jose, USA, with 160 milliseconds latency
- 2) The Australian variant www.netflix.com.au (which would be expected to be hosted more locally) translates to a different server detour2.prod.netflix.net [52.32.78.165], which is also located in San Jose at 160 milliseconds away (but is a different server from that identified in (1) above).
- 3) Looking into the content server that streams the television and movie content to the user (which is actually the performance that would be relevant to be measured) – the content URL is media.netflix.com, which resolves to d22vsig0v5rjtf.cloudfront.net [13.224.175.102], which is only 10 milliseconds latency located within Sydney, using the CloudFront content caching system.
- 4) However, for most ISPs their movies are generally distributed from Netflix's OpenConnect libraries, which are physical library servers generally hosted at IXPs and within ISPs internal networks (<https://media.netflix.com/en/company-blog/how-netflix-works-with-isps-around-the-globe-to-deliver-a-great-viewing-experience>)

Performing a simplistic 'ping test' or 'traceroute test' to www.netflix.com would result in an answer of 160 milliseconds as its latency performance – however this number has no relation to the actual performance of the video streaming service.

6.5. Simplistic testing to headline website names is not sufficient

A simplistic performance measure might be to find the round-trip latency to the website using the traceroute tool, or a ping tool:

Internet (World Wide Web) Latency Test Methodology



```
C:\Windows\System32>
C:\Windows\System32>
C:\Windows\System32>
C:\Windows\System32>
C:\Windows\System32>
C:\Windows\System32>
C:\Windows\System32>
C:\Windows\System32>
C:\Windows\System32>
C:\Windows\System32>
C:\Windows\System32>tracert www.airbnb.com.au

Tracing route to e864.b.akamaiedge.net [23.40.75.248]
over a maximum of 30 hops:
  0  <1 ms    <1 ms    <1 ms    192.168.0.1
  1  9 ms     10 ms   11 ms    loop180150680.bng1.vdc01.syd.aussiebb.net [180.150.68.1]
  2  9 ms     9 ms    10 ms    be5.core1.equinix-sy1.syd.aussiebb.net [180.150.1.157]
  3  13 ms    9 ms    12 ms    HundredGigE0-0-0-8.core1.vdc01.syd.aussiebb.net [180.150.1.184]
  4  12 ms    66 ms   31 ms    ae3.vocus-syd2.netarch.akamai.com [23.56.128.129]
  5  8 ms     10 ms   12 ms    a23-40-75-248.deploy.static.akamaitechnologies.com [23.40.75.248]

Trace complete.
C:\Windows\System32>
```

This suggests the website www.airbnb.com.au is approximately 10 milliseconds of round-trip latency away, however we noted earlier than many of the elements were hosted in other servers up to 200 milliseconds away.

This test isn't testing performance to the headline website, it is testing to (and from) the nearest Akamai Technologies cache, which is used to host many of the most popular websites across the globe.

Similarly a test of www.netflix.com or the Australian www.netflix.com.au websites would indicate poor performance with latency around 160 milliseconds – yet this would be a misleading conclusion as the actual streaming service content is served locally, no more than 10 milliseconds latency away.

6.6. To measure popular website performance, concentrate on the global CDNs

Today, all the most popular Internet destinations are hosted on the main CDN and content accelerator platforms, distributed around the world. Even small websites incorporate elements sourced from the global platforms for usage monitoring, and to appear in directory searches and boost rankings in search engine listings (especially using Google and Microsoft elements).

To measure the performance of end-user Internet services and the underlying access networks - and Internet service providers - in providing access to these global platforms and content, it is sufficient to measure the performance and reachability from the user to the main CDN accelerator services (and in the return direction back to the user), including:

- Google
- Microsoft
- Amazon AWS
- Amazon CloudFront
- Akamai Technologies cache
- Fastly
- CloudFlare
- LimeLight Networks

Internet (World Wide Web) Latency Test Methodology

These global content accelerator services are generally physically served out of the larger data centres across the globe, located in major capital cities and focal point of global Internet traffic.

Scope of This Study

7. Scope of This Study

This study and report was commissioned by the Internet Society as a project to support UN-ESCAP, in support of a study item identified at the *Subregional workshop on implementation of the Asia-Pacific Information Superhighway for achieving the Sustainable Development Goals in Pacific island countries*²⁰ to examine the feasibility of establishing a regional IXP in the Pacific.

The study will be titled “Pacific Regional IXP Feasibility Study” and the high level “Scope of work” has been agreed between ISOC and ESCAP, as highlighted below:

- Review current Pacific Islands submarine cable inter-connectivity (i.e. which countries are linked directly by cable to each other)
- Find out latency to the current major surrounding content hubs (Australia, New Zealand, Singapore, USA West Coast) from member countries
- Tabulate number of international gateways in the Pacific Islands and their international connection hub (i.e. where does the international link terminate for traffic exchange)
- Consult with the Member countries and find out the available capacity of these submarine cables
- Based on above data, assess technical feasibility of establishing a regional Pacific IXP and if feasible, potential location and structure
- Review policies of Member states to establish IXP in the country which can then be connected to regional IXP, check if additional licenses are required (no legal review required).

²⁰ <https://www.unescap.org/events/subregional-workshop-implementation-asia-pacific-information-superhighway-achieving>

Scope of This Study

END OF REPORT