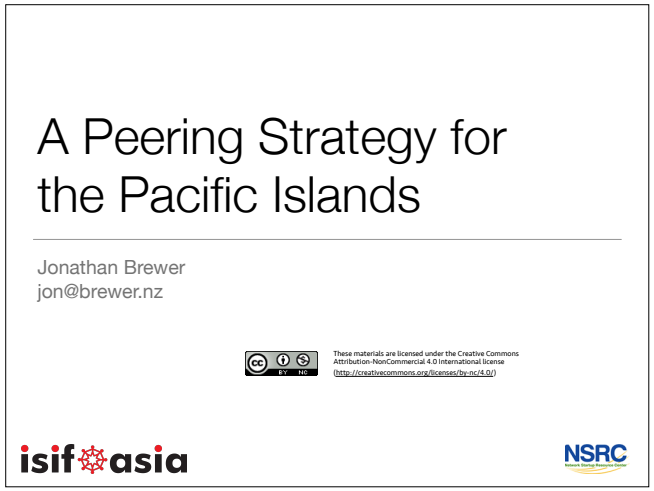
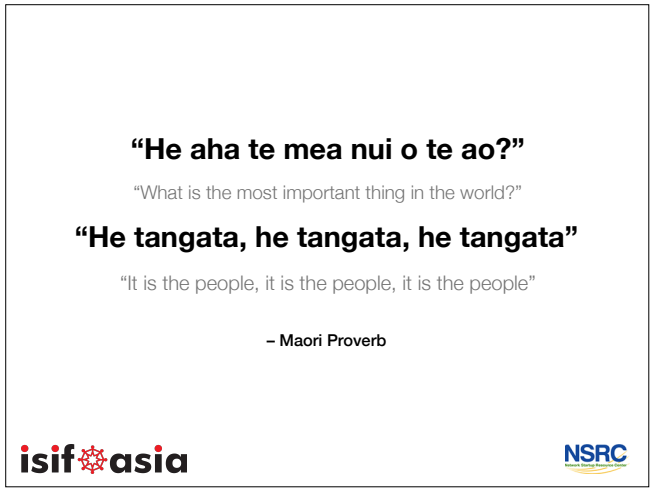


Kia ora koutou. I'm Jon Brewer, a network engineer based in Wellington New Zealand. This talk discusses preliminary findings from a larger body of work in progress around connectivity and Interconnectivity in the Pacific. I'd like to thank the Network Startup Resource Center for funding some of the early work discussed here today, and the Information Society Innovation Fund for work since June 2015.

I've been involved in PacNOGs as a trainer for NSRC, teaching network management & security workshops in Tonga, Fiji, Vanuatu, the Solomon Islands, Samoa, and now Guam. It's and a privilege to be with you this week to share this conference with you.



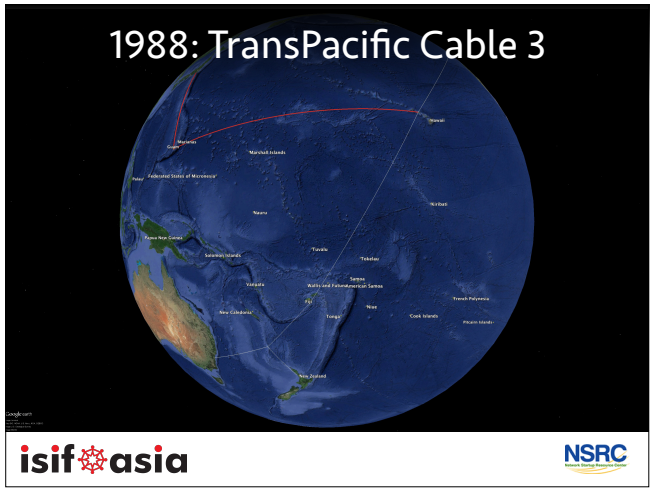
Why am I working on a long-term project looking at network interconnections? My interest in the Internet is in how it connects people.

I'd like to thank the University of Oregon's Network Startup Resource Center and the Information Society Innovation fund - and its administrator APNIC - for support of this year-long project.

Connecting People in the Pacific is an intersection of a few problem spaces.

This first section of the talk is about submarine cables. Building cables may seem to be a technical problem, but in fact it's commercial and political motivations that shape how, where, and when submarine cables are built.

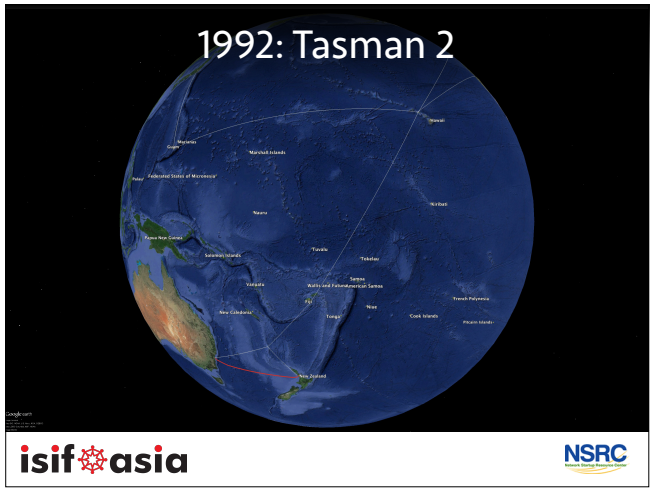
This was the state of the Pacific in the late 1980s. ANZCAN linked Canada, Hawaii, Fiji, Norfolk Island, Australia, and New Zealand, with 1380 analogue channels, 480 of which branched off to New Zealand at Norfolk Island. ANZCAN wasn't fibre, but it carried the first Internet traffic to New Zealand.



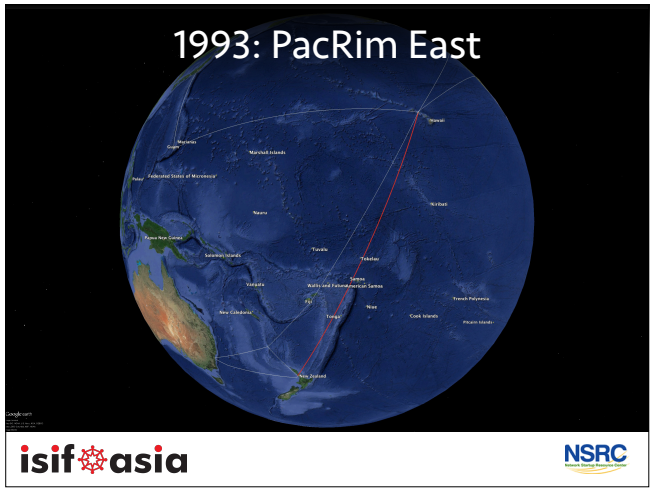
TPC3 has the honour of the first commercial submarine fibre optic cable in the Pacific.

Two fibre pairs, each lit at 280 mbps, from Japan to Guam to Hawaii.

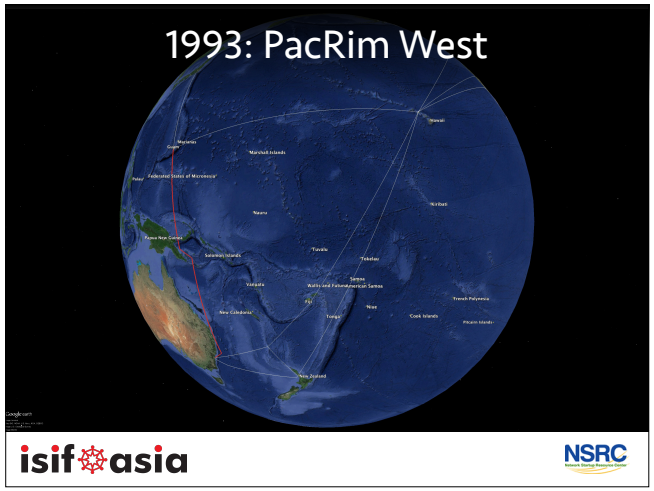
The US mainland gained fibre optic service shortly after in 1989 with HAW-4, a single 280mbps pair from California, after which things quieted down for Pacific Islands for a bit.



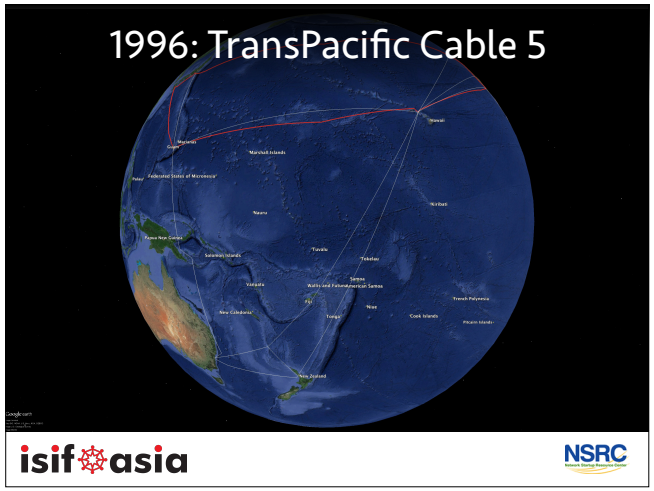
New Zealand's entry into submarine fibre came in 1992 with the lighting of Tasman 2 between Whenuapai and Sydney. Not exactly a standalone project, Tasman 2 was soon joined by…



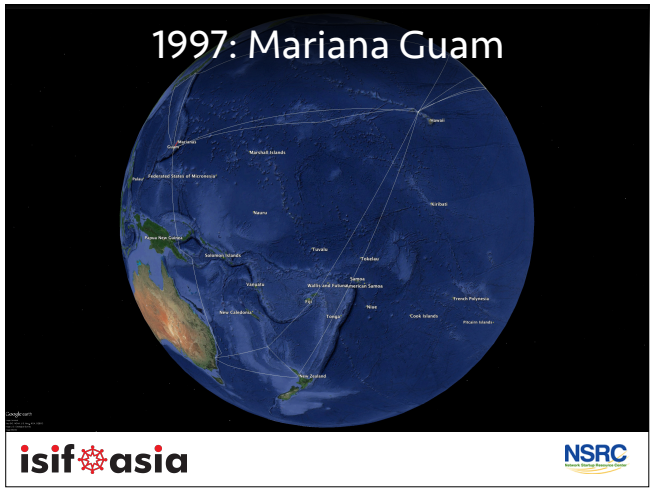
PacRim East, joining Hawaii and Takapuna at 560mbps.



and PacRim West, joining Sydney to Guam, also at 560mbps. Not a lot of capacity, and as we'll see, these cables don't stick around all that long.

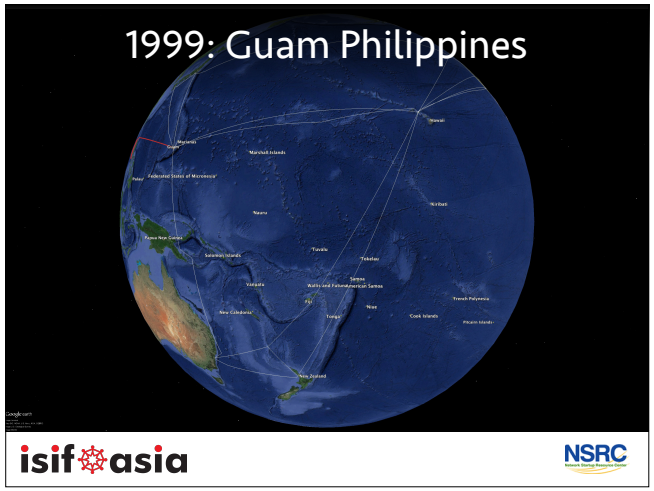


In 1996 TPC 5 lights up two pairs at 5gbps each (2x STM-16, with 32 155mbps circuits available) in a loop connecting the US, Hawaii, Guam, and Japan. That's starting to sound like real capacity, at least for the 90s. Note Hawaii and Guam both starting to become important waypoints.



1997 brings our first island hopper cable in the Pacific, the Mariana Guam cable. 240km long, three islands of which Saipan is the biggest, and 6x 622mbps carriers. You're excused if you can't see the change on the map. Just a note, an ISP complained to me recently that they were quoted $20k a year for a T1 on this cable.

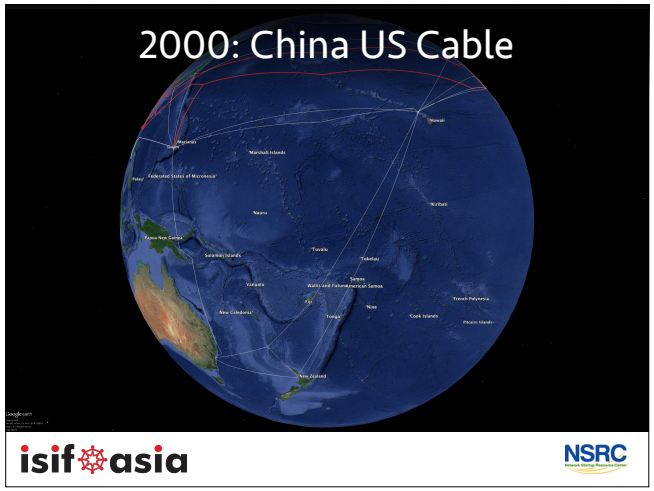
This cable failed in early July when a Typhoon hit the Marianas and Guam-Saipan communications was out for around three weeks as a cable repairs were assessed and a ship sent from Hong Kong.



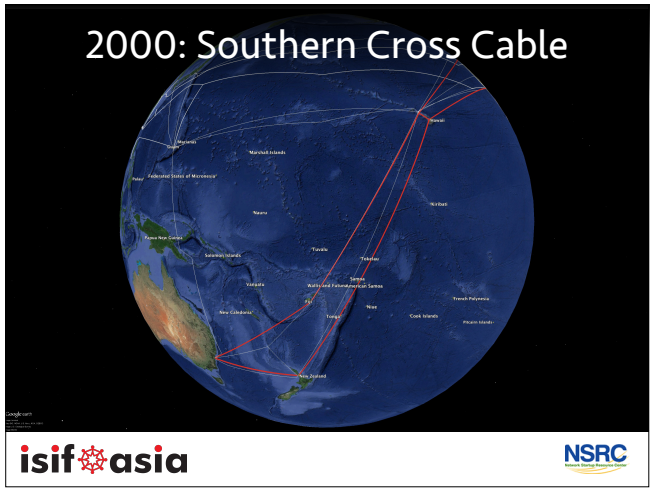
About the time Neil Stephenson was writing Cryptonomicon, a brilliant piece of fiction about cryptography, submarine fibre, and data havens, Hitachi Cable was laying a 3600km cable between Guam and the Philippines.

We're just getting into dotcom boom times, and fibre laying is kicking into overtime. Guam - Philippines was only one of more than twenty submarine fibre cables laid in 99, but still, this cable cements Guam in its role as a major waypoint for submarine fibre in the Pacific. It's another step change in capacity too.

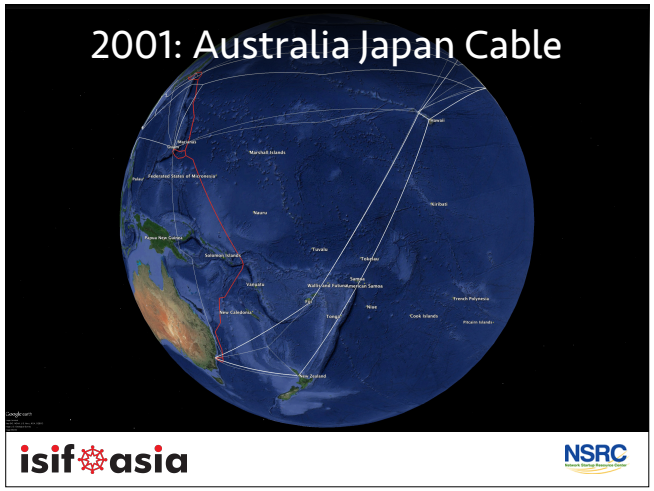
Remember just three years ago TPC5 lit a 10gbps ring from the US to Japan? Well Guam Philippines started life with 50 gbps of capacity, by way of 21 2.5gbps carriers.



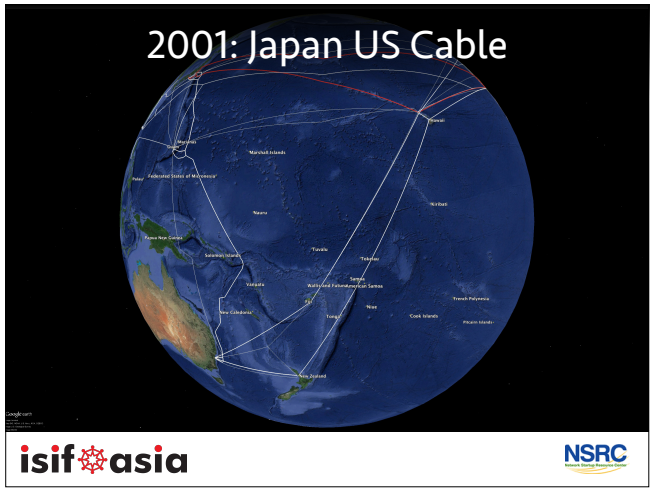
With Guam quickly becoming a hub, the China US cable drops 40gbps into Guam via a branching unit. As with Guam Philippines, Guam is now a destination, not just a waypoint.



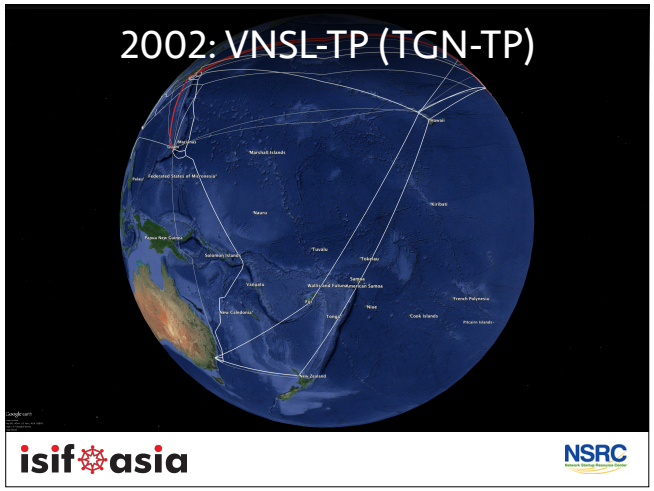
Finally New Zealand gets some love. Southern Cross is lit with 80gbps and an original design capacity of 250gbps. That's been pushed beyond a terabit by this point.



More love for Australia and for Guam with a 320gbps cable between Australia and Japan in 2001. And we see the decommissioning of PacRim East. Rest in peace PacRim East.



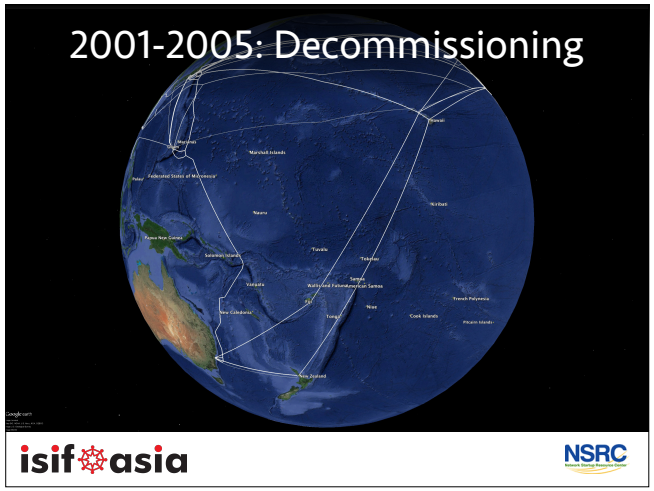
And a top-up for Hawaii in 2001, as a new cable from the US to Japan passes through with 320 gigabits per second. Hawaii - or at least O'ahu, is now as busy as Guam when it comes to cables. Capacity was doubled in 2008.



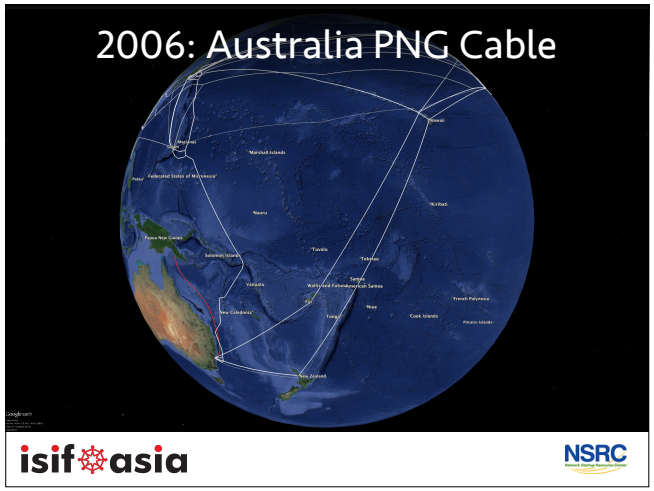
2002 brings the decommissioning of ANZCAN and the introduction of VNSL Transpacific (A project begun as Tyco Transpacific, and now now known as TGN TransPacific), nominally a US Japan cable. It was planned and implemented as a 5 terabits per second cable, another step change for capacity in the Pacific.

When I first researched The Transpacific I thought its capacity to Guam was intentional, a branch coming down from Japan to meet other cable networks. In fact, TGN-TP was intended to be a loop connecting California, Hawaii, Guam, Japan, and Oregon.

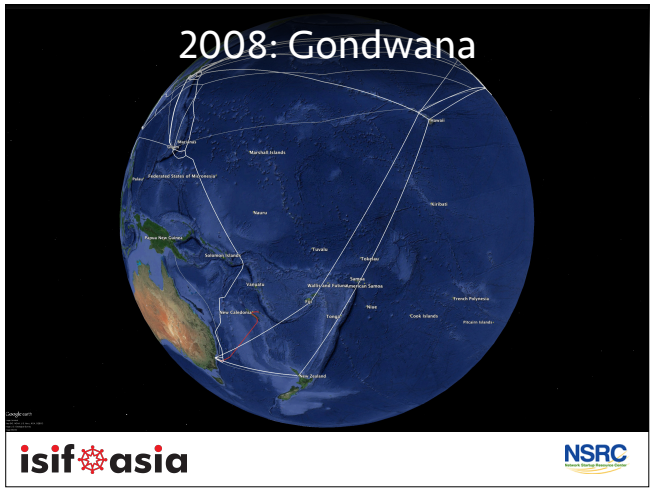
Due to difficulties with permission to land their cable in Hawaii, Tyco abandoned a newly constructed cable station in Hawaii and some cable build in California, and left its spur into Guam as somewhat of an orphan. Today it is bundled together with other cable networks to create solutions that pass through Guam but don’t actually stop.



With their limited capacity, the short-lived PacRim cables are decommissioned - NZ to Hawaii in 2001, and Australia to Japan in 2005. We lose TPC-3 in 2003, HAW-4 in 2004, and HAW-5 in 2005. But all is not lost.

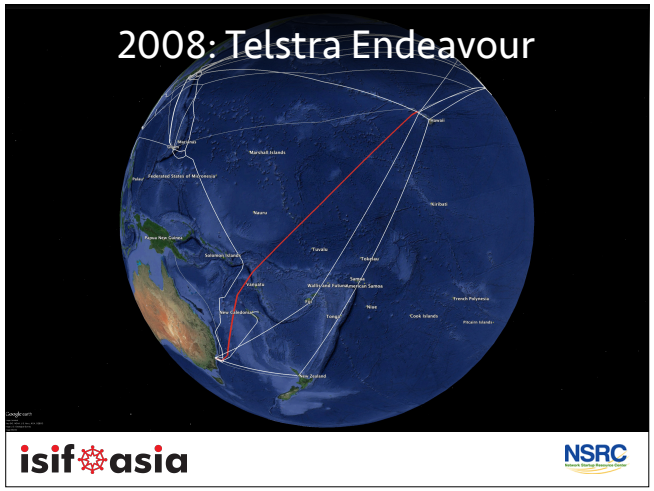


2006 has the cold, dead snake of PacRim West dragged off the seafloor and hauled to Port Moresby - recommissioned with a design bandwidth of just over a gigabit per second. From what I understand, regeneration in this cable is electronic, not optical, and E5 (565mbps) is as fast as electronic regeneration will work. So we've got two 565mbps pairs bringing a total of 1.1 gigabit per second into PNG.

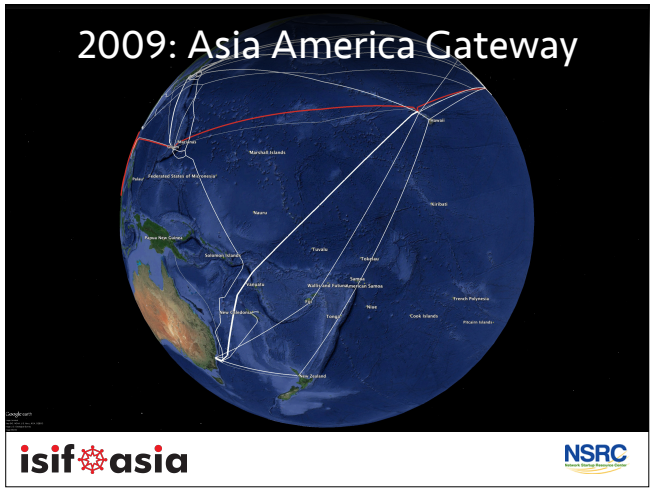


New Caledonia is the first major island infill project, with a new cable from Sydney lit at 20gbps in 2008. Likely taking advantage of idle Alcatel staff who would otherwise be waiting around to fix issues on Southern Cross.

Just a couple more k and they'd have made it to Vanuatu, but that didn't happen..

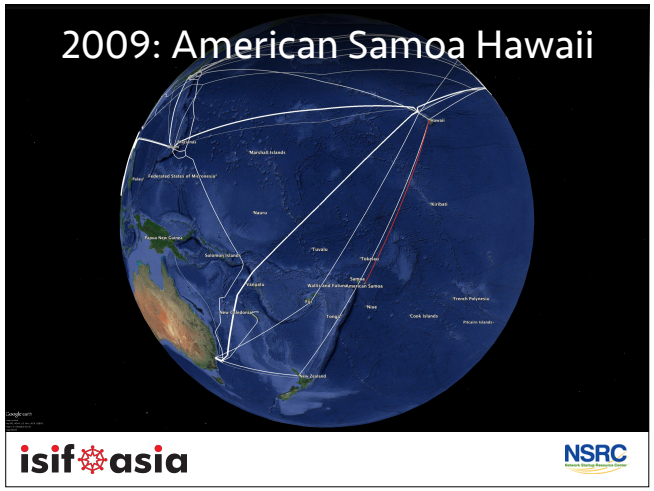


Also in 2008, Telstra lays a new cable directly from Sydney to Hawaii, bypassing Vanuatu, the Solomons, New Caledonia… You'd think they could have saved money combining efforts with Gondwana, but if there's anything I've learned about submarine cables it's that people don't cooperate. Endeavour is a 1.28 terabit per second cable.

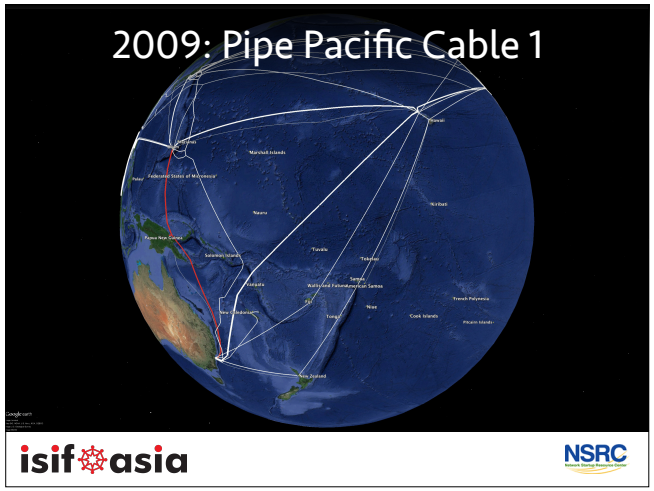


In 2009, we have the commissioning of the Asia America Gateway.

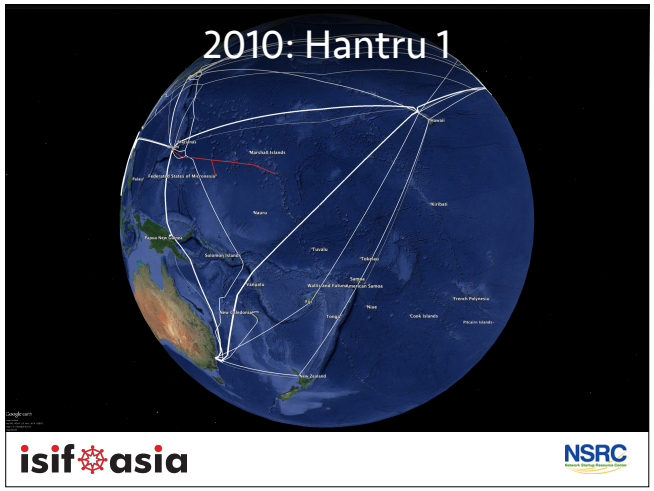
California, Hawaii, Guam, and then on to Asia. Initially half a terabit, but upgraded to 5 in 2011. At the same time , Tata's TGN Intra-Asia is installed from Singapore to Guam via Hong Kong and the Philippines. There's now an awful lot of bandwidth in and out of Guam.



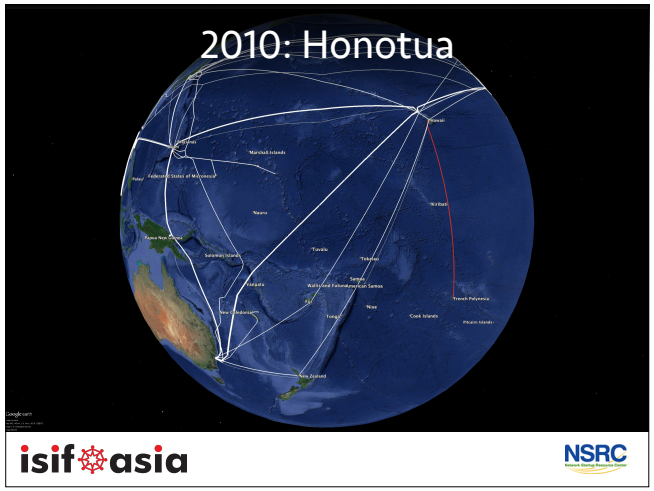
Also in 2009 we see another resurrection of the PacRim cable, this time the east section from Hawaii to Samoa. The cable is cut and hauled up to the Samoas and recommissioned at 1.1 gigabit per second as was done with PacRim West and Papua New Guinea. Sure it's 1/500th the capacity of the new AAG cable, but it's better than satellite.



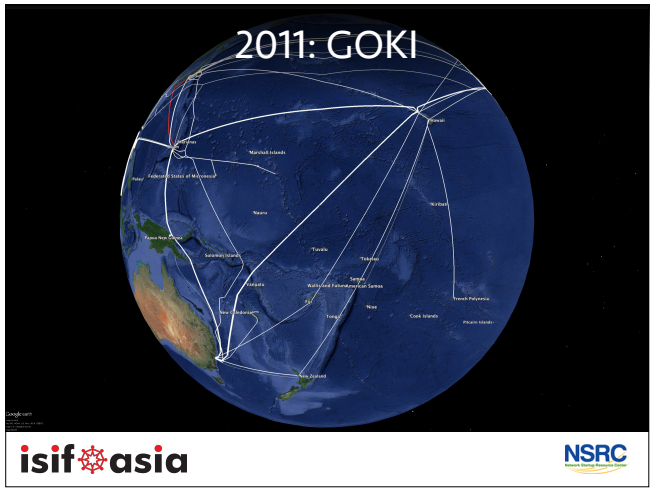
Rounding out 2009 we have Pipe's PPC1, which shoots north to Guam (anyone surprised?) at 1.9 terabits per second with a branch to PNG, and potential for four more branches in between. Though the potential is there, one of the operators who could take a branch thinks it'll be cheaper to build his own cable to Sydney.



More Pacific infill comes about with a 20gbps cable linking Guam to Micronesia and the Marshall Islands. It's been reported this project relied on the US military as an anchor tenant.

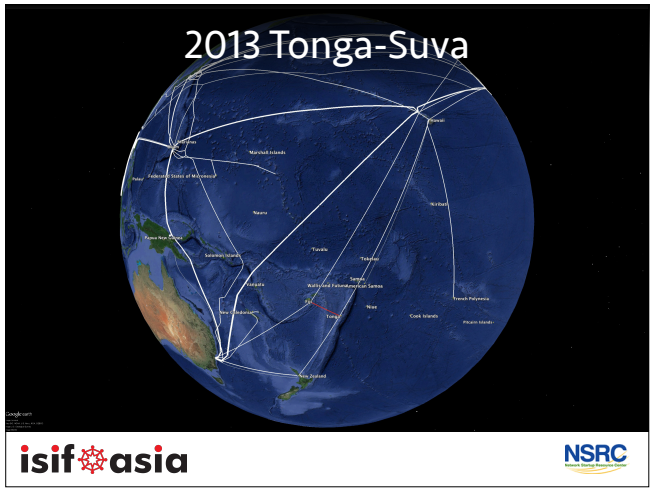


And one more big Pacific project in 2010: Alcatel's 320gbps cable from Hawaii to French Polynesia. This is a big deal - if you remember from the last section of my presentation on distance, Tahiti is just about as far away as you can get from the rest of the world. Sure it was only lit with 2x 10gbps, but that's not bad for a set of islands with a quarter million people on them. That cable was turned up to 2x 40gbps in mid-2015.

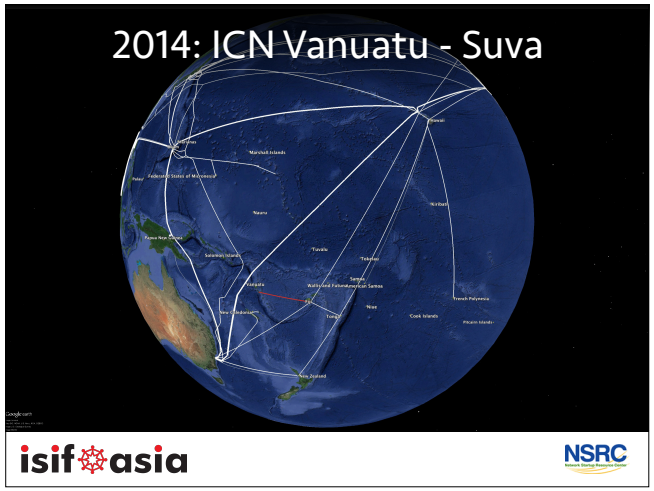


In 2011 we remove at least some of TPC-5 from service, and add a half-new cable called GOKI. 80gbps reported. What needs a direct path from Guam to Okinawa to Korea? I can think of one customer looking for a low latency path controlled by AT&T the whole way. Are any commercial providers using it? No idea.

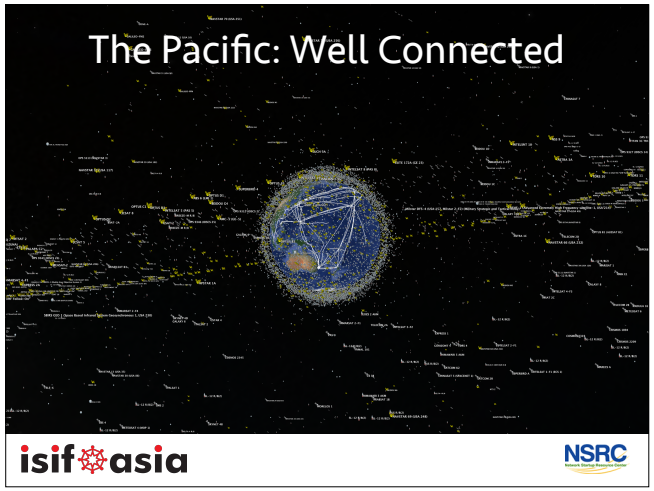
I've taken all of TPC-5 off the map, but one provider tells me there are bits still in use - now unprotected I guess, and likely used by similarly unnamed customers.



The last two years have seen two more small projects built by Alcatel Lucent Submarine Networks: the Tonga Suva cable in 2013 lit up at STM-16…



and last one, the ICN cable from Vanuatu to Fiji in 2014. While both were deployed with initial capability of 20gbps, neither has more than a few hundred mbps in use.



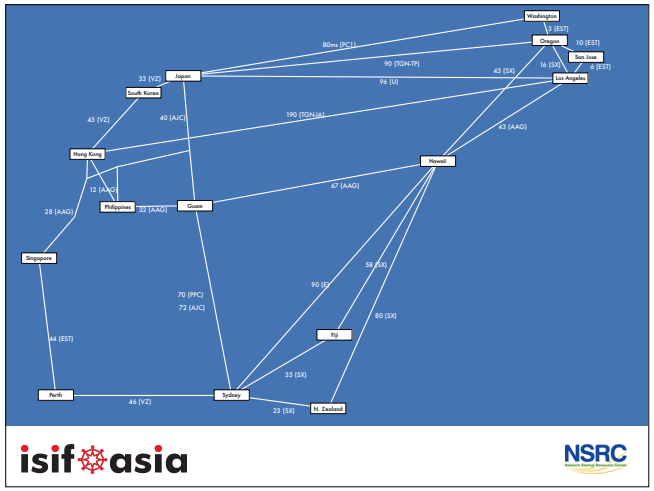
Taking the larger view - with cables and satellites in place - the Pacific is extraordinary well connected. Its major hubs Hawaii, Fiji, and especially Guam, have the potential for fast, low latency connections to the entire Asia Pacific region - and North America - and soon to Europe via a polar cable network.

That map, by the way, was the actual position of every satellite and named space object currently in orbit when I captured that image.

Let’s talk about Guam.

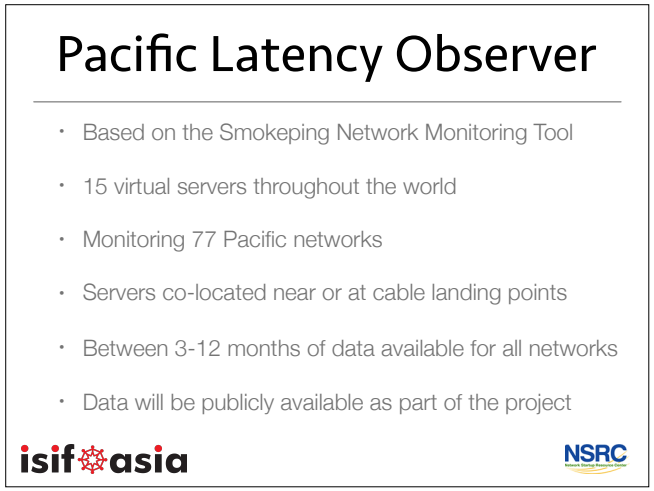
Guam is a highly diverse island . Native Chamorro people account for 37% of its population.
Filipinos, Pacifica peoples, and Asians make up nearly 56%.
Guam is the nearest developed market to both the Federated States of Micronesia (FSM) and the Republic of the Marshall Islands (RMI).
Many Micronesian islanders come to Guam for education and work opportunities, and the two territories are connected to the world via submarine cables that land in Guam.
Guam's main industry after the military is tourism from Asian countries. Guam has a plethora of Japanese, Korean, and Chinese tourists, and hotels, restaurants, and shops catering to these visitors.

Guam is one of the best locations in the world when it comes to submarine cable connectivity. Let's see how they're taking advantage of all those cables.



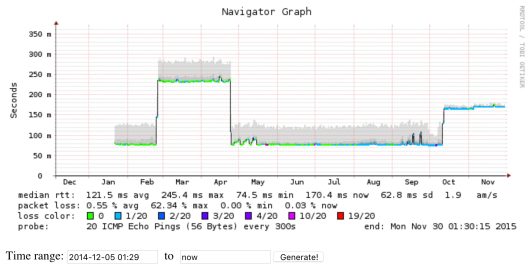
I've constructed a simple model of cables in the Pacific and network latencies to look at how Guam connects to the rest of the world. Providing the best performance for real-time tasks like Skype, Facetime, and distance learning applications means keeping latency down.

Ideally all of Guam's carriers would reach Japan directly, via the Australia-Japan cable, or TGN-TP cable. They'd access China and Southeast Asia via the China-US cable, the Asia-America Gateway cable, or the Guam-Philippines cable. They'd access Australia, New Zealand and Fiji via the AJC cable or PPC-1 from Guam to Sydney. And finally Guam carriers would reach Hawaii via the AAG cable or TPC-5.



I'm tracking how well the providers are performing with a set of servers I call the Pacific Latency Observer

Pacific Latency Observer



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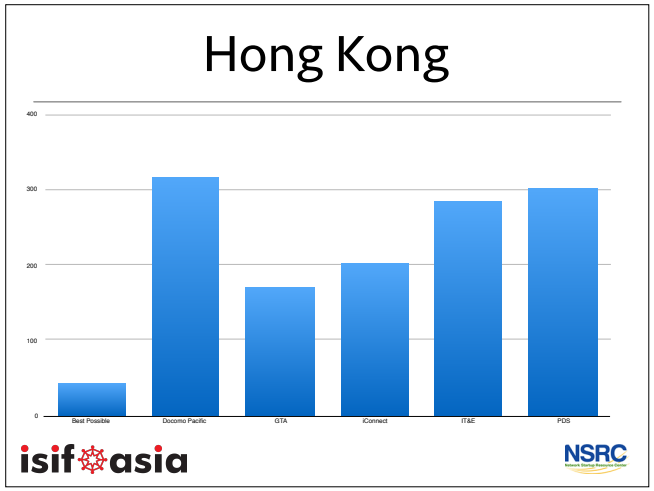
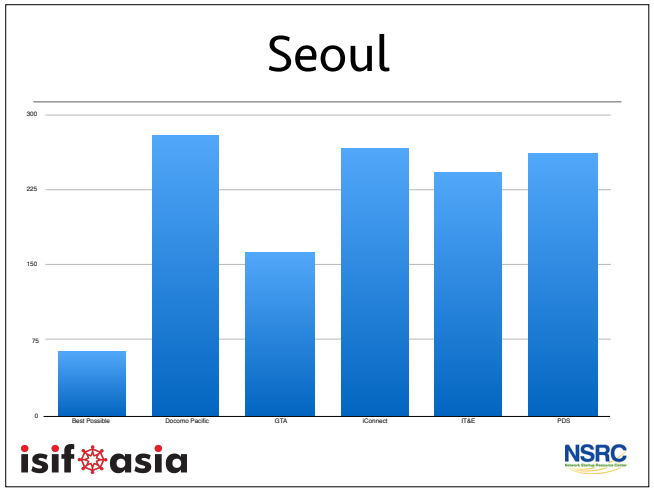
In this chart we're looking at the latency between local carrier GTA and a server I have co-located at the Honolulu Internet Exchange. We can see the carrier has at times had direct connectivity to Honolulu, but has also shifted their connectivity to much longer routes in March and April, and a somewhat longer route in October.

The next set of slides is the median RTT from a couple of locations to each of the Guam carriers.

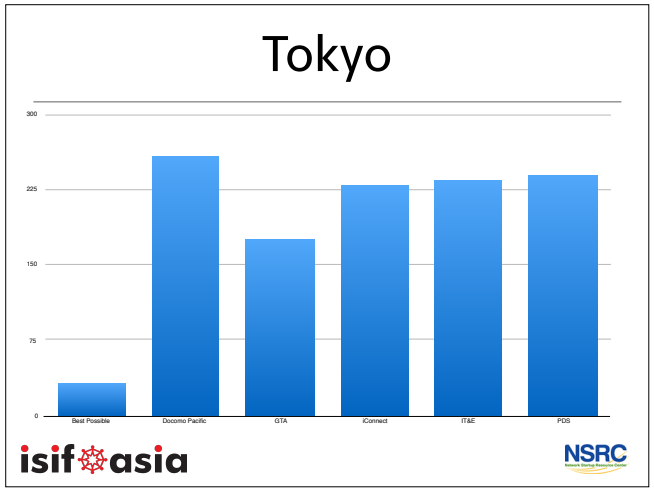


Hong Kong is a good source of tourists for Guam, and there are daily direct flights. Taking the AAG cable directly, it can take 44 milliseconds. Taking a slightly less direct service on Tata's TGN-TP and TGN-IA cables, you can make it in 72 miliseconds.

It appears from my measurements all Guam carriers access Hong Kong via transit links in the US.



Korea is also a good source of tourists for Guam. The best possible path to Seoul takes 65 milliseconds from Guam. GTA appears to have a route for which not all traffic transits the US, but the remaining carriers head to the west coast of the US first.

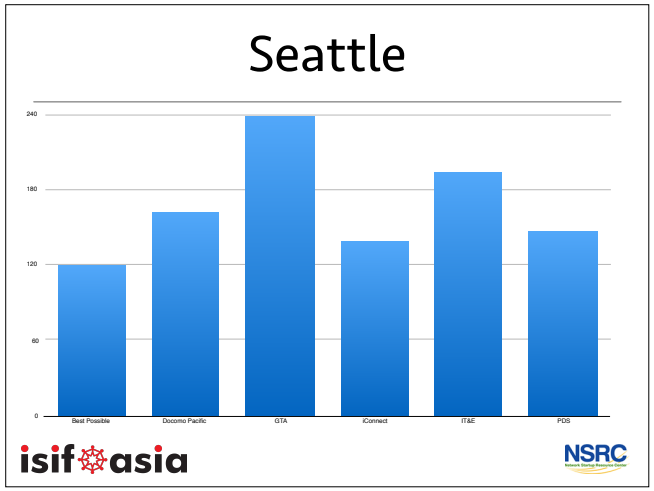


Japan is Guam's major source of tourists. In the last year, 779,405 Japanese visitors came to Guam. I bet nearly every single one of them took photos with their camera phones. Many of the, shared photos with their friends at home. Many likely phoned home over the Internet - and judging from the Guam-Tokyo performance I've found, they probably had a poor experience.

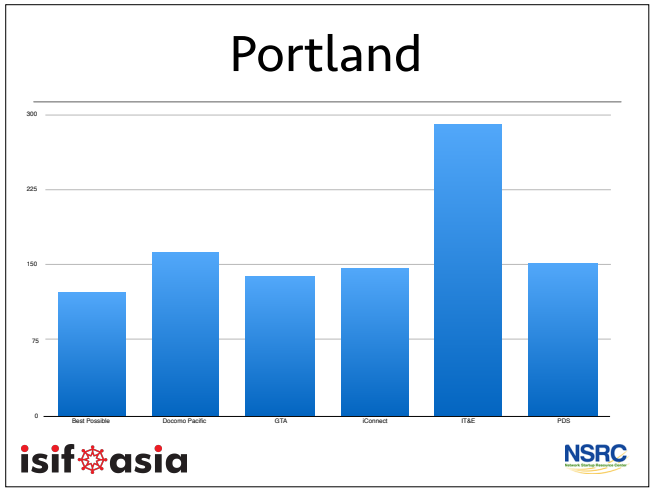
Tokyo is 31 milliseconds from Guam. There are two direct cables to Japan, and one of them, the Australia Japan Cable, has two different landing points on Guam. None of Guam's carriers are using these cables to access Japan.

Nearly 800 thousand Japanese visitors a year are coming to Guam and having an unnecessarily poor Internet experience.

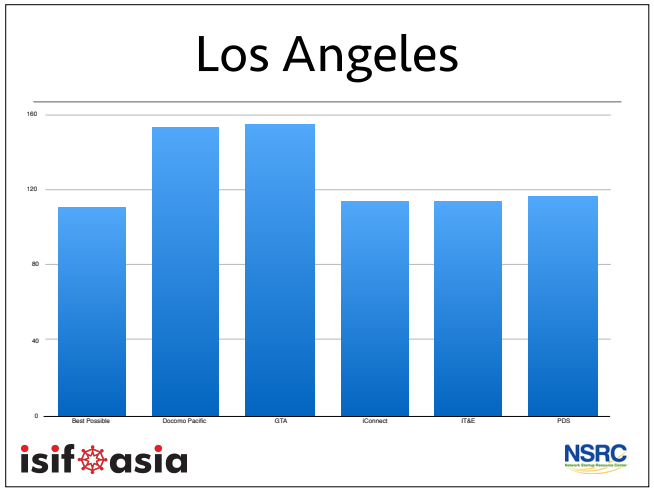
I'll just point out now that this is not a problem shared by the Marshall Islands or Federated States of Micronesia. Both have links to Tokyo, and spectacularly good performance as a result.



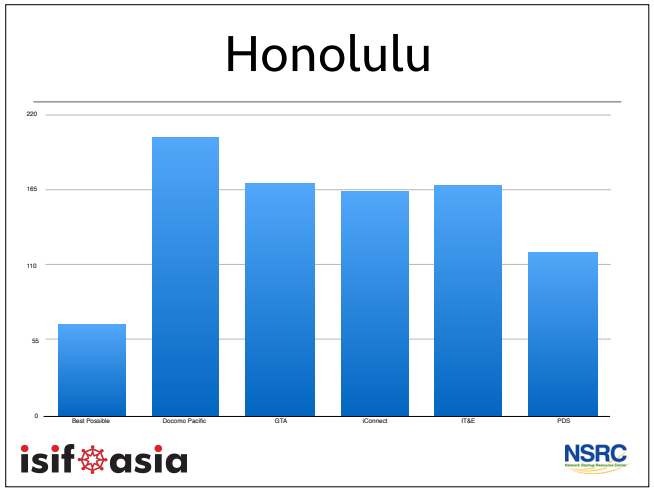
It's when we get to the West Coast of the US that things start looking better. The best possible path to Seattle is around 120 milliseconds, and mot carriers make it in less than 200.



Portland is even better. The best possible path to Portland is 122 milliseconds, and most carriers make it around the 150 millisecond mark. I don't know how many tourists Guam gets from Portland every year, but I bet it isn't 800 thousand.

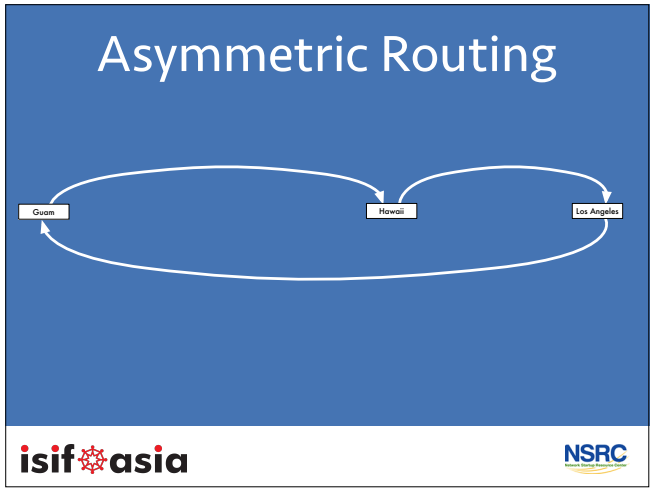


Los Angeles is where three of Guam's five carriers have near-perfect performance, and the other two have very good performance.



Honolulu, on the other hand, is a very different story from Los Angeles. There's a significant, long-term bond between Hawaii and Guam. There's a long-term exchange of people and commerce that's important to both states.

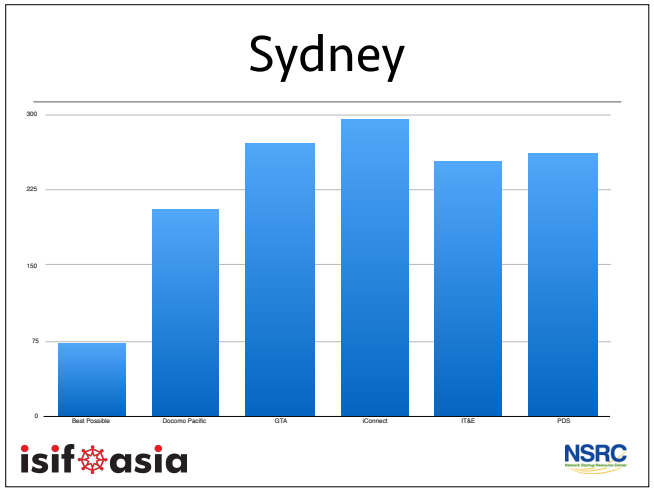
There are two cables between Honolulu and Guam, and taking one of those cables the trip can be made in 67 milliseconds. Of the ISPs, only PDS has a direct link, and even then much of their traffic takes asymmetric routes,



A quick note on Asymmetric Routing.

With our best performer between Guam and Honolulu, the ISP called Pacific Data Systems, it appears from my measurements that data is routed asymmetrically. From a server at the Honolulu Internet Exchange, the best route I can find for PDS is via Los Angeles. All of my traffic goes to California first, before going to Guam. On the way back, from Guam it appears to route directly to Hawaii.

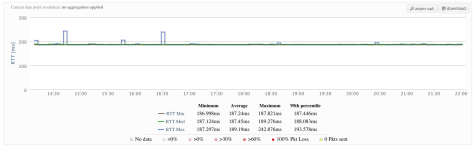
This concept of asymmetric routing results in slower than necessary performance, and sometimes strange network problems. It's not confined to the Guam Hawaii path or PDS though. I see asymmetry with IT&E in Singapore, with GTA in Hong Kong, Seoul, and Tokyo.



Finally a look at Sydney, and via Australia the best possible access to New Caledonia, Papua New Guinea, Auckland, Fiji, Vanuatu, and Tonga. Two cables run between Guam and Sydney - The Australia Japan Cable and Pipe Networks' PPC-1. None of Guam's ISPs take advantage of the low cost and low latency on these cables, resulting in extremely poor performance for access to South Pacific networks.

RIPE Atlas Project

- RIPE Atlas is a network of probes
- Measuring Internet connectivity & reachability
- Using DNS, HTTP, ICMP, and NTP



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Another way I'm looking at Pacific network performance is through the RIPE Atlas Project.

RIPE Atlas is a network of probes…

RIPE Atlas Probe

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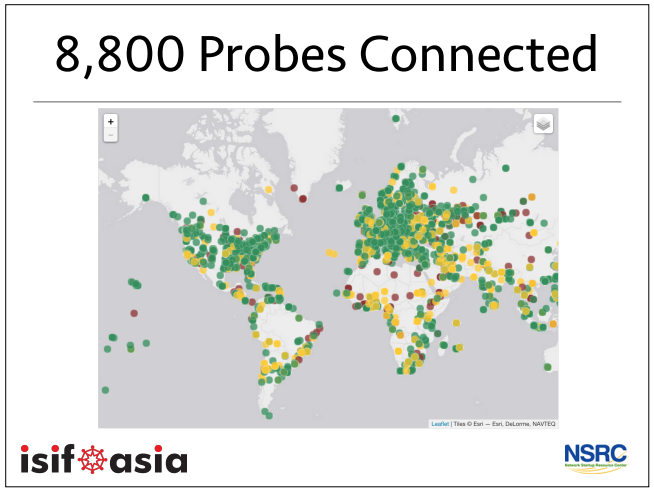
The devices look like this: They're tiny, they take very little electricity, they're secure, and they're useful.



Here's a view of the RIPE Atlas network as of September 2015. Many of those dots in the Pacific are probes I've distributed as a part of my project this year.

Atlas in the Pacific

American Samoa, Australia, Cook Islands, Guam, Fiji, French Polynesia, Hawaii, New Caledonia, New Zealand, Niue, Philippines, Samoa, Tonga, Vanuatu

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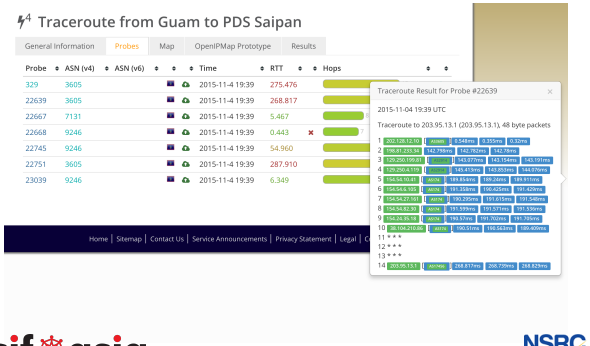
Atlas Measurements



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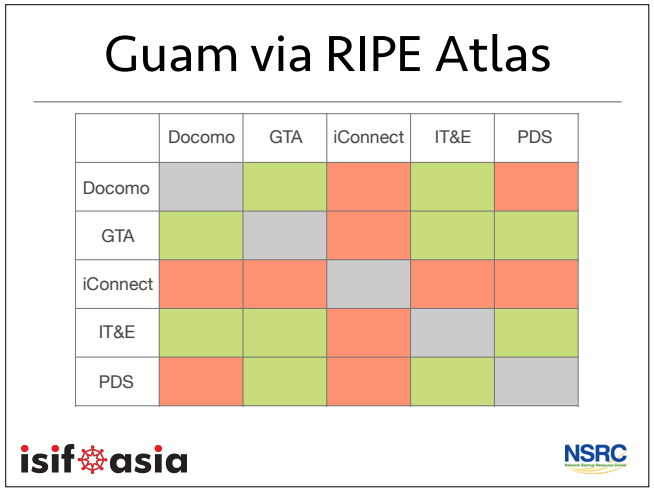
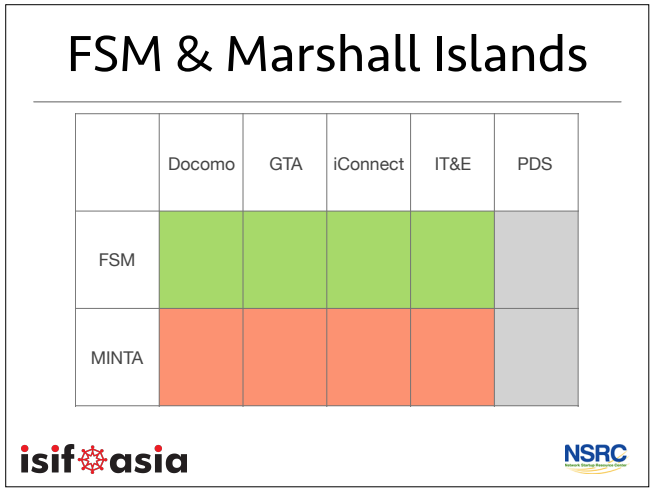
Some of the types of measurements I'm doing with Atlas are traceroutes, where I select a group of hosts around the Pacific, and see how they connect to other Pacific networks.



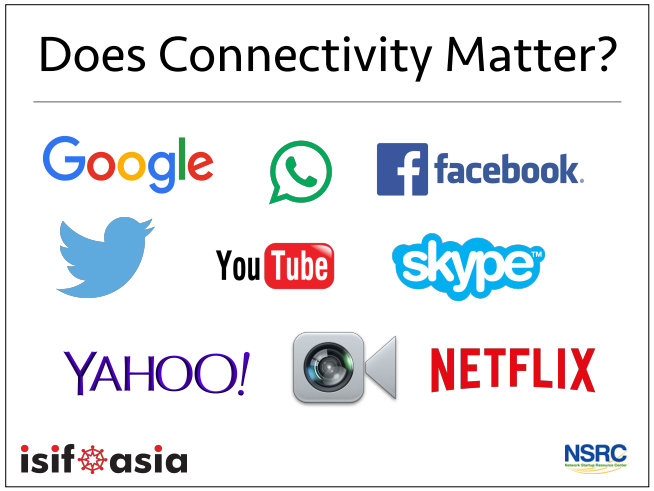
Here's the results of a set of traceroutes between the various carriers in Guam. We can see that not all of Guam's carriers interconnect locally - and some, like iConnect, send all of their traffic directly to the United States, not peering any of it on-island.



Here's the results of a set of traceroutes from Guam carriers to the Federated States of Micronesia and to the Marshall Islands. PDS is not represented here as they do not host a RIPE Atlas Probe, and MINTA's RIPE Atlas probe has been offline for many months.

Does Connectivity Matter?

- Email - not so much
  - However in Niue email between carriers takes hours
- Facebook - not so much
  - Conversations are in “near-real-time”
- **VoIP? Skype? FaceTime? Yes! Yes! Yes!**
- **Streaming Media? Yes**



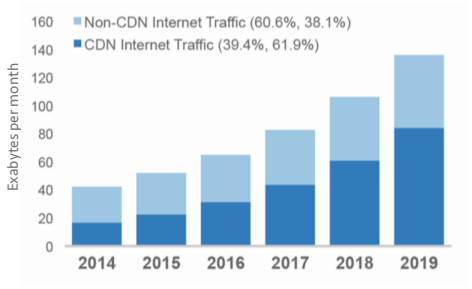
Facebook and Twitter are in essence about people communicating with people, though depending on your friends, communication via Facebook could be entirely made up of cat videos. But they're not typically person-to-person communication, and not typically in real-time.

YouTube, Netflix, and Yahoo on the other hand, are about consuming content - streaming media content. And they're a tremendous drain on network resources.

The apps here that really connect people to people are Whatsapp, Skype, and Facetime.

Of all of these services, the ones that consume the most Internet resources are the streaming video applications. The ones that consume the least resources are the person-to-person communications applications.

Traffic from Content Delivery Networks



Global Content Delivery Network Internet Traffic, 2014 and 2019

http://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/VNI_Hyperconnectivity_WP.pdf

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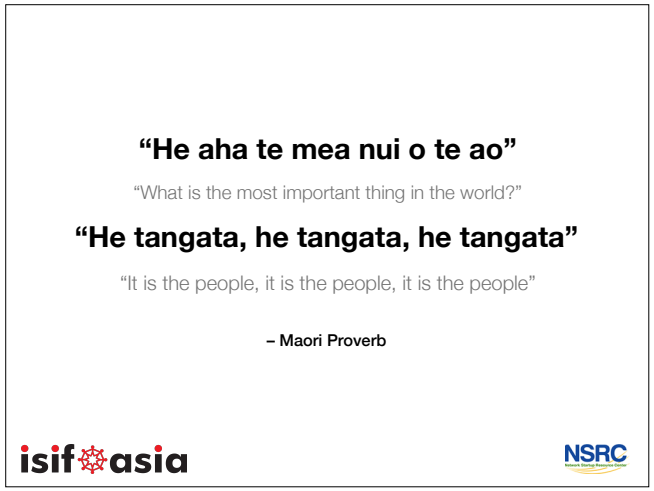
As our colleague Mats from IJI mentioned earlier, CDNs are a major part of traffic The big streaming and social media services are a growing proportion of the Internet's traffic, and by 2019 Cisco predicts their traffic will be 62 percent of all Internet traffic.

They've also have changed the way the Internet works significantly. They're no longer a server in a data center in Los Angeles. Today they're global networks, with data centres and points throughout the world, and cache servers and appliances frequently located within customer networks.

Planning high-capacity, low latency connections to CDN nodes is an important task for network engineers.



The Internet is a big place, and even if we're headed for a world where 2/3 of our traffic is commercial content, we care about the one third. We still care about the delivery of personal letters in a day when most paper mail is invoices or advertisements. We certainly still care about personal emails in a time when the great volume of email - either from companies we've purchased from or plain old spam.

Performance of person to person connectivity - especially for real-time applications like VoIP, Skype, and FaceTime, depends on how networks are connected to each-other.

A Peering Strategy
for the Pacific Islands

Throughout my research I've been asked - especially by carriers - what are you going to do with all of this information? What's the purpose of your project? Is this all going to go in a report and never get seen again?

My intention is to identify gaps in knowledge and produce a strategy for filling them. Roughly this help falls into categories described on the next few slides.

Real-time and historic visibility of network is generally lacking in the Pacific, and its lack makes network operations and planning difficult.

Understanding your top talkers will allow you to understand where you should be peering, purchasing bandwidth, or installing caching appliances.

Looking to your customers is important! I’ve spoken with many pan-Pacific organisations in the last few month who have terrible performance between their branch offices because of US-centric routing.

Help: Transit & Peering

- All transit is not equal
  - A link without committed latency can go anywhere
- Lack of understanding of transit purchase strategies
  - Long-term agreements must predict growth
- Lack of understanding of peering strategies
  - Free peering is great, paid peering is also ok

Help: Streaming Media

- CDN content is available in the Pacific at Tokyo or Sydney
  - There's no reason to take CDN traffic from Los Angeles
  - Closer content is cheaper content
- Latency matters for CDN/Streaming Media Access
  - TCP rx windows restricted to improve CDN throughput
  - Distant users suffer to increase performance for all

Help: RIPE Atlas Project

- Probes are free for networks - even multiple probes
- Assistance is available for many tasks beyond setup
  - Monitoring & Systems integration
  - Visibility from the world
  - Custom Measurements

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Next Steps: ISIF Project

- Integrated Pacific Performance Website Online
- Analyse Benefits of Regional Peering Points
  - Does every country need an exchange? Maybe not.
- Assess needs for training & assistance
  - Network Visibility, Transit & Peering, CDNs, Atlas

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This is my wrap-up for now. In addition to handing out Atlas probes, I'll be interviewing users, carriers, and regulators in a number of countries to explore what's going on, and what we can do to help. If you'd like to get involved, please get in touch.


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