3rd September 2025

Network State Checking

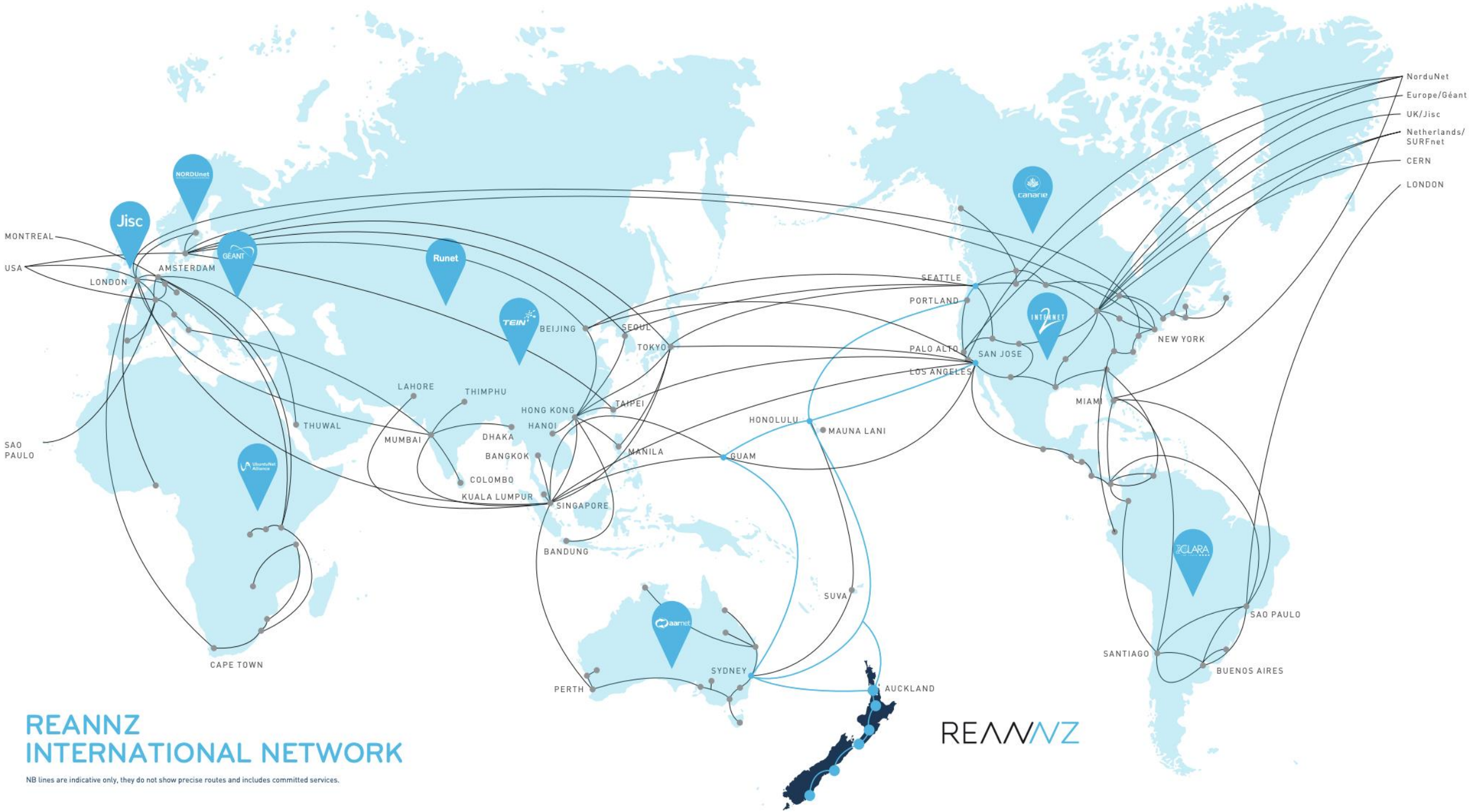
A Case Study in Automation

REANNZ


Seattle
Sydney
Hawaiki Capacity
REANNZ NATIONAL NETWORK MAP
NB lines are indicative only

Who?


120 Global Research & Education Networks
National Network Operators
Managed Service Providers
REANNZ
Specialist network operators | Global connectors
Technical experts for the research and education sector
Tertiary Institutions
Research Institutes
Government Agencies
Galleries, Archives, Libraries, Museums



REANNZ INTERNATIONAL NETWORK

NB lines are indicative only, they do not show precise routes and includes committed services.

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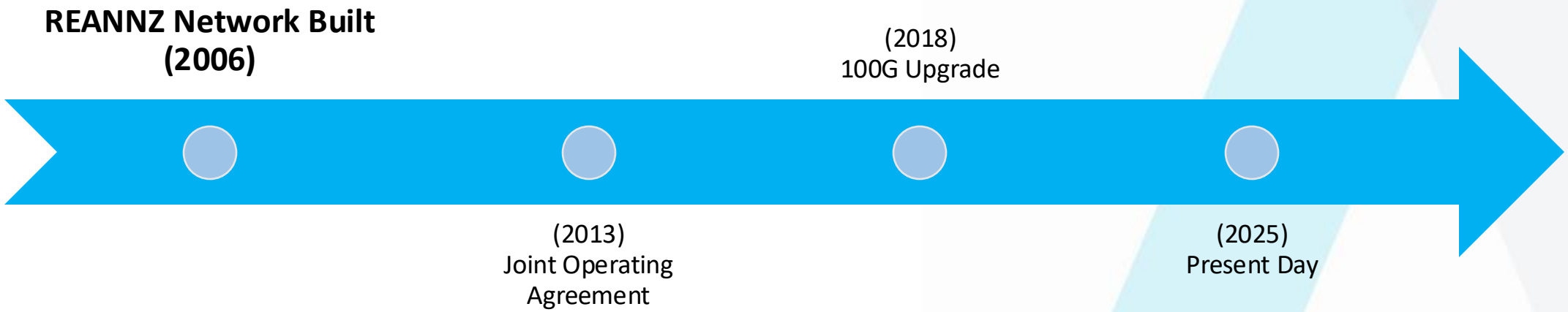
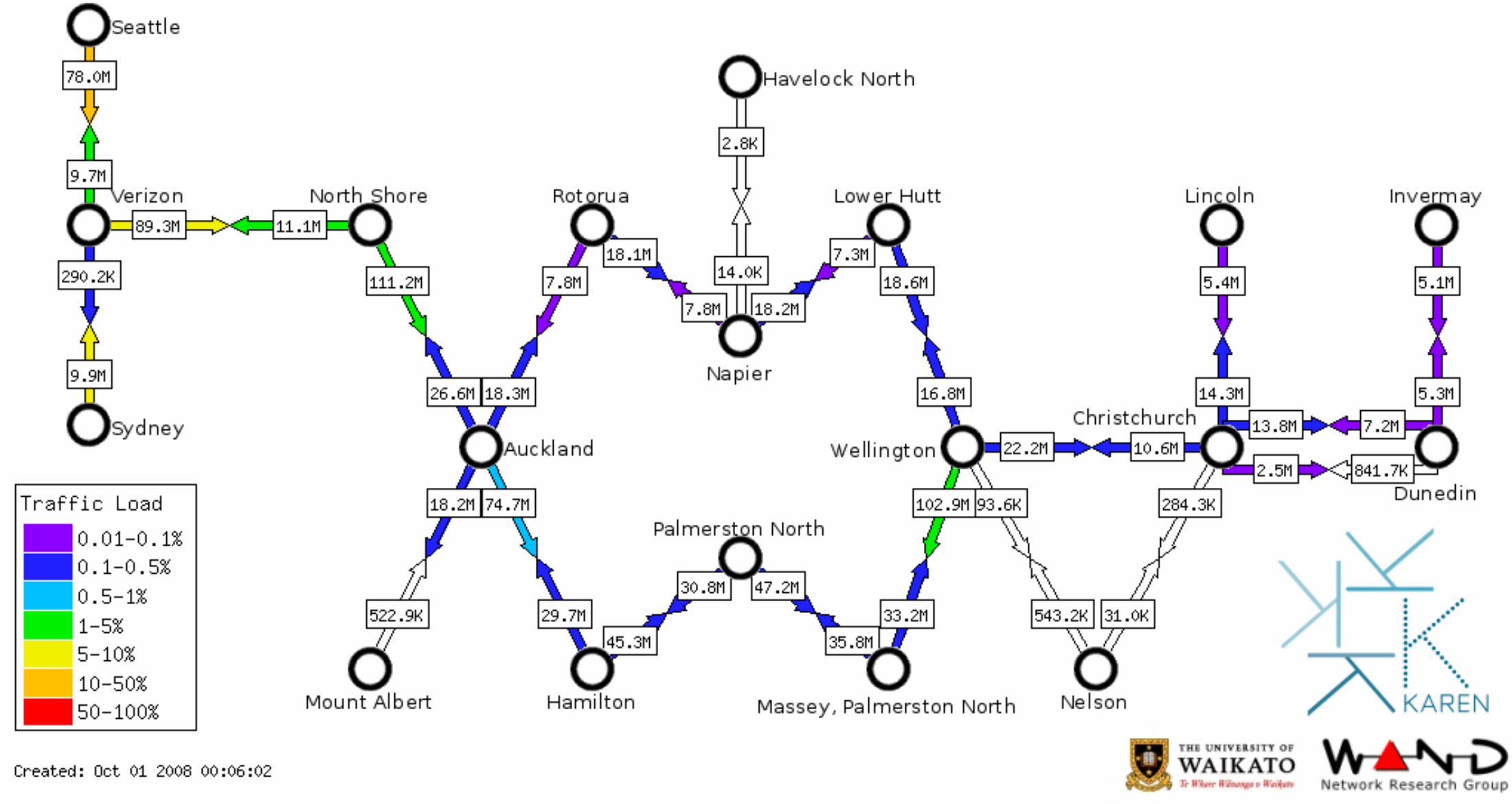
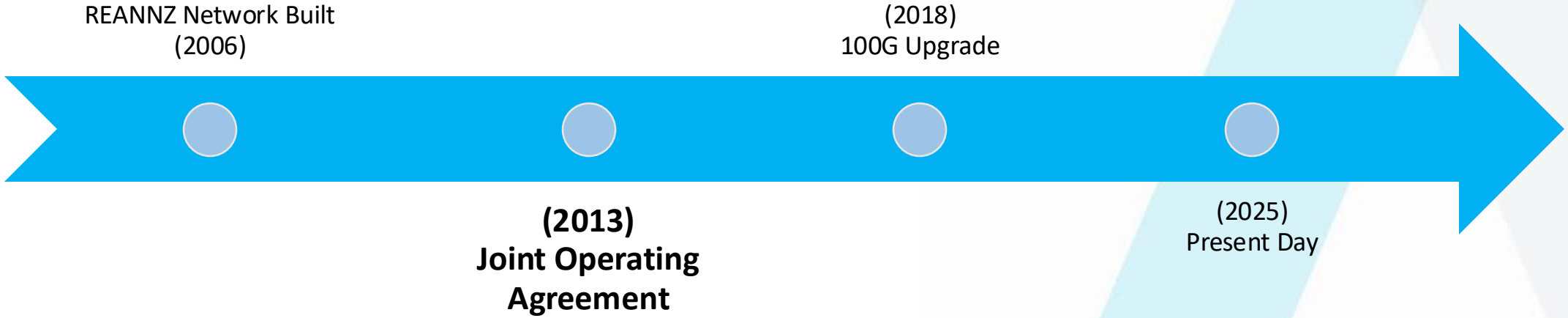
A Changing Network



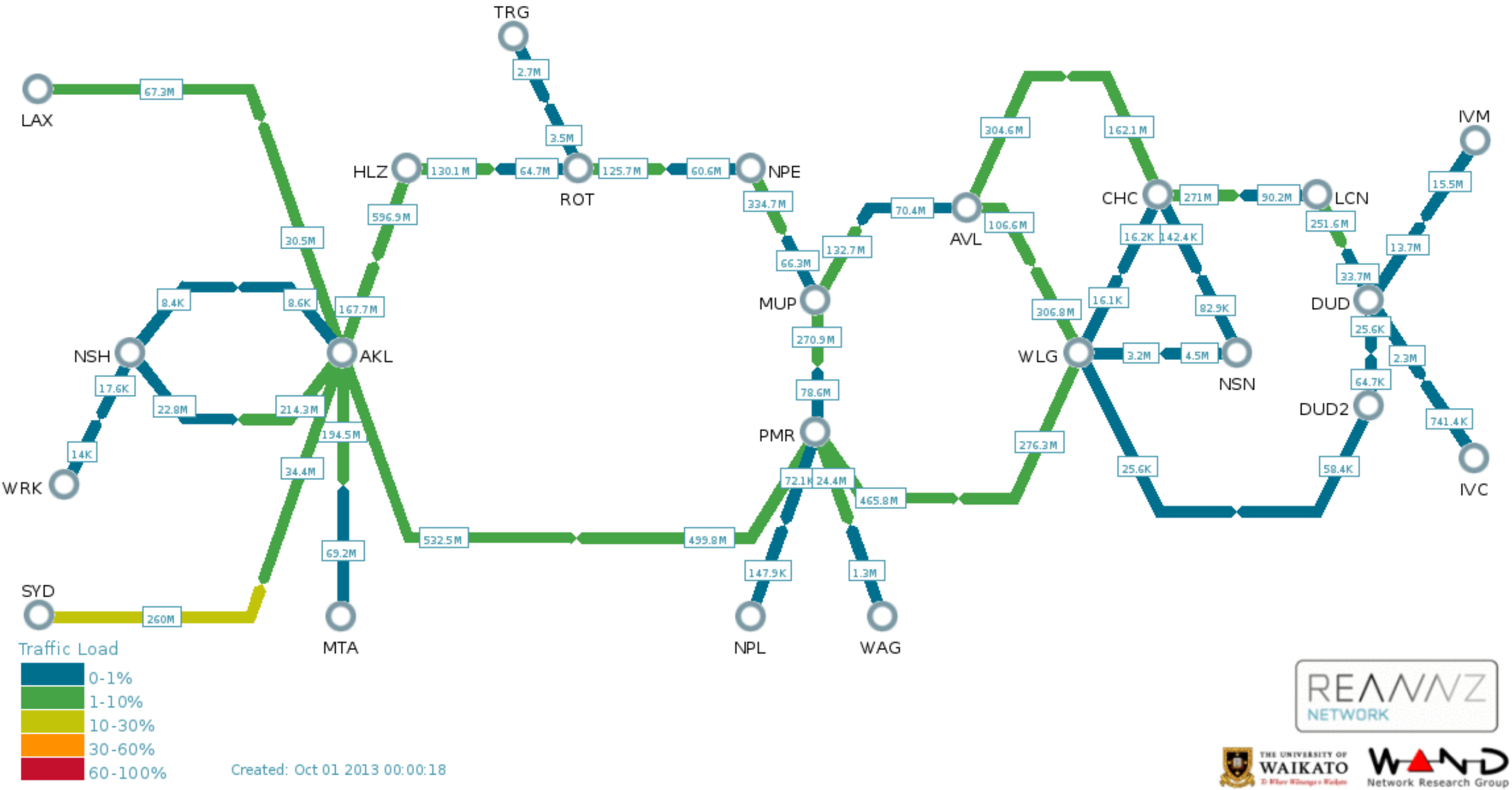
REANNZ


Seattle
78.0M
9.7M
Verizon
89.3M
11.1M
North Shore
290.2K
9.9M
Sydney
111.2M
Rotorua
7.8M
18.1M
Havelock North
2.8K
14.0K
7.8M
18.2M
Napier
Lower Hutt
7.3M
18.6M
16.8M
Lincoln
5.4M
14.3M
Invermay
5.1M
5.3M
Christchurch
13.8M
7.2M
2.5M
841.7K
Dunedin
26.6M
18.3M
Auckland
Wellington
22.2M
10.6M
18.2M
74.7M
102.9M
93.6K
284.3K
Palmerston North
30.8M
47.2M
522.9K
29.7M
33.2M
543.2K
31.0K
45.3M
35.8M
Mount Albert
Hamilton
Massey, Palmerston North
Nelson
Traffic Load
0.01-0.1%
0.1-0.5%
0.5-1%
1-5%
5-10%
10-50%
50-100%
KAREN
Created: Oct 01 2008 00:06:02
THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato
WAND
Network Research Group

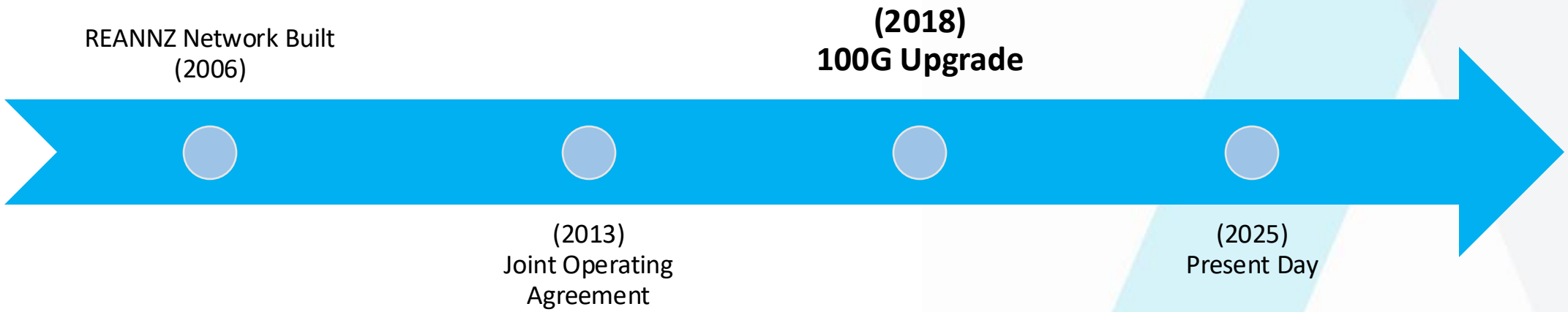
A Changing Network



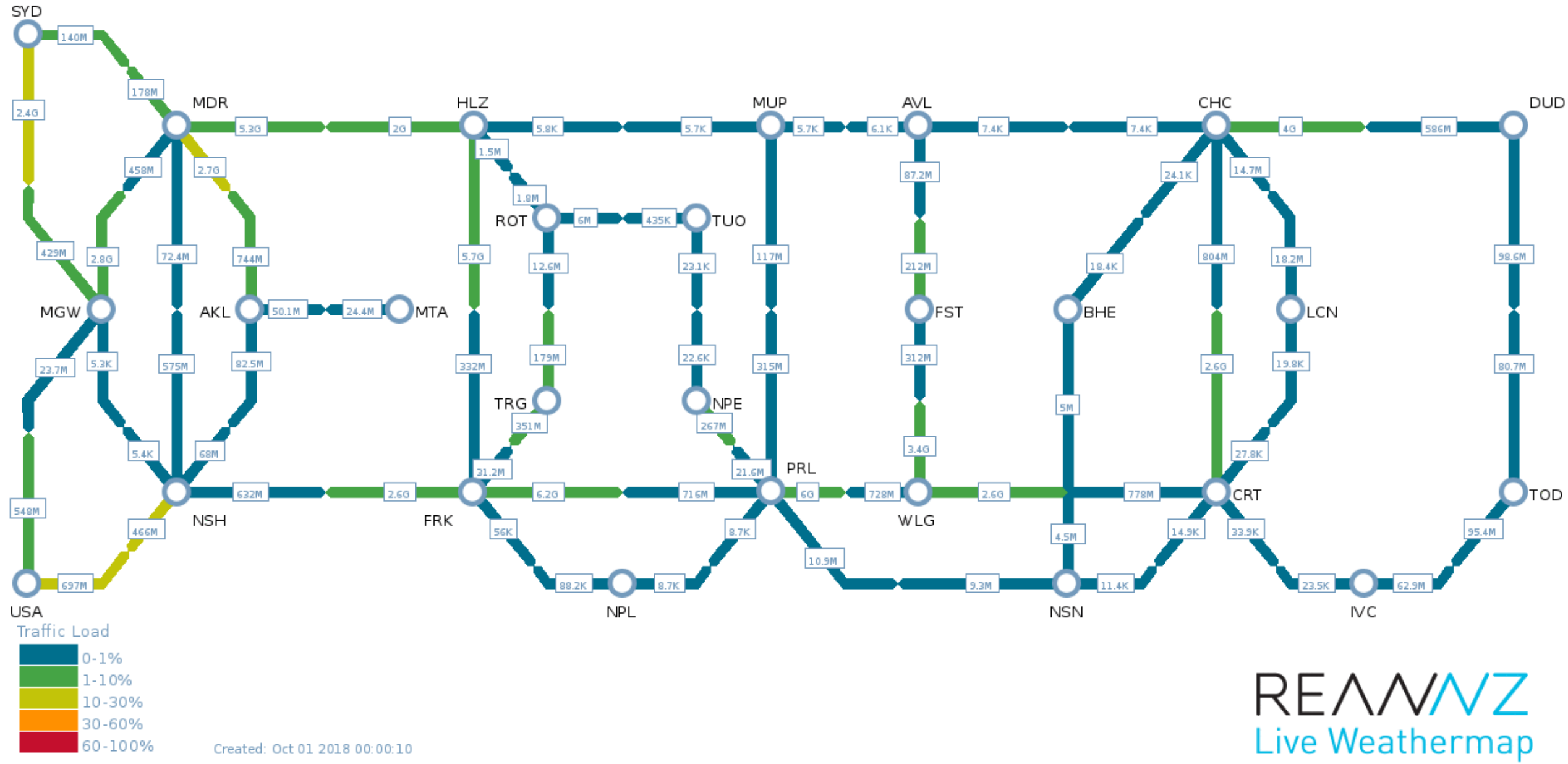
REANNZ


TRG
2.7M
3.5M
LAX
67.3M
HLZ
130.1M
64.7M
ROT
125.7M
60.6M
NPE
IVM
15.5M
304.6M
162.1M
334.7M
70.4M
AVL
CHC
271M
90.2M
LCN
106.6M
16.2K
142.4K
251.6M
596.9M
30.5M
132.7M
66.3M
13.7M
33.7M
MUP
DUD
8.4K
8.6K
167.7M
16.1K
82.9K
306.8M
25.6K
NSH
AKL
270.9M
WLG
3.2M
4.5M
NSN
2.3M
17.6K
22.8M
214.3M
78.6M
64.7K
DUD2
194.5M
PMR
741.4K
276.3M
14K
34.4M
25.6K
58.4K
WRK
72.1K
24.4M
465.8M
IVC
69.2M
532.5M
499.8M
SYD
147.9K
1.3M
260M
MTA
NPL
WAG
Traffic Load
0-1%
1-10%
10-30%
30-60%
60-100%
Created: Oct 01 2013 00:00:18
REANNZ
NETWORK
THE UNIVERSITY OF WAIKATO
WAND
Network Research Group

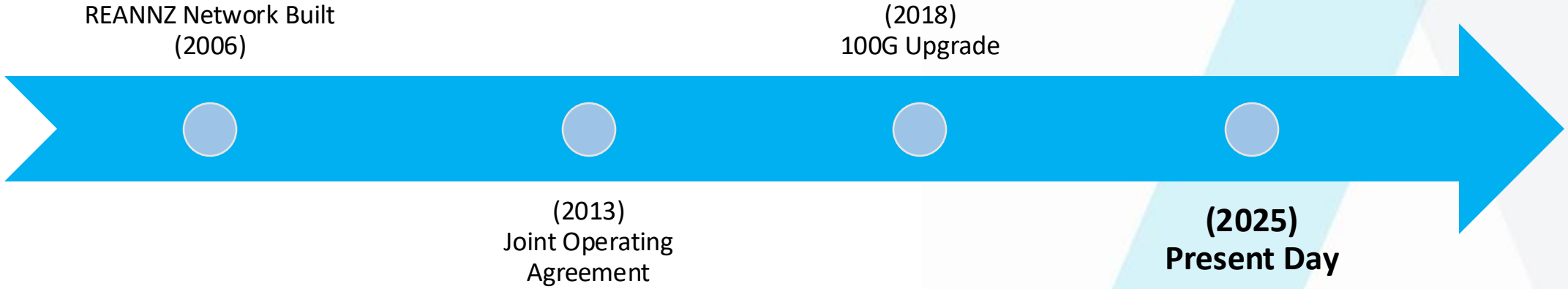
A Changing Network



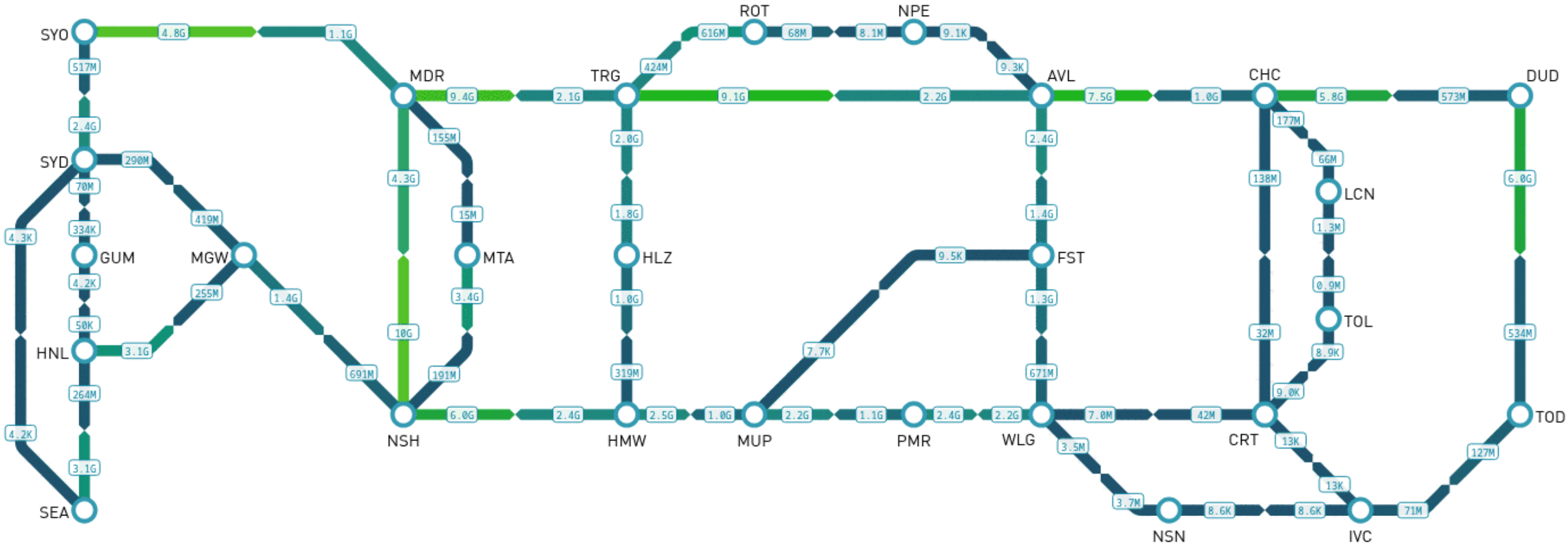
REANNZ


SYD
MDR
HLZ
MUP
AVL
CHC
DUD
ROT
TUO
MGW
AKL
MTA
FST
BHE
LCN
TRG
NPE
PRL
NSH
FRK
WLG
CRT
TOD
USA
NPL
NSN
IVC
140M
178M
2.4G
5.3G
2G
5.8K
5.7K
5.7K
6.1K
7.4K
7.4K
4G
586M
1.5M
1.8M
6M
435K
458M
2.7G
87.2M
24.1K
14.7M
429M
2.8G
72.4M
744M
5.7G
12.6M
23.1K
117M
212M
18.4K
804M
18.2M
98.6M
50.1M
24.4M
23.7M
5.3K
575M
82.5M
332M
179M
22.6K
315M
312M
5M
2.6G
19.8K
80.7M
351M
267M
5.4K
68M
31.2M
21.6M
3.4G
27.8K
548M
632M
2.6G
6.2G
716M
6G
728M
2.6G
778M
466M
56K
8.7K
10.9M
4.5M
14.9K
33.9K
95.4M
697M
88.2K
8.7K
9.3M
11.4K
23.5K
62.9M
Traffic Load
0-1%
1-10%
10-30%
30-60%
60-100%
Created: Oct 01 2018 00:00:10
REANVNZ
Live Weathermap

A Changing Network



REANNZ



Traffic Load

0% 15% 40% 70% 100%

Aug 30 2025, 12:00AM

REANNZ

Network Automation

> 2006 – 2014 | Hand-built Configurations

Initially, the REANNZ network was entirely built by hand. Network service templates were not generally well-defined or standardised, introducing risk with every change.

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Network Automation

> 2014 – 2019 | One-off Scripts

Some changes were gradually recognised to merit the development of scripting to assist in their completion.

- VPLS Meshing
- MPLS Core LSP/iBGP Meshing
- Member RPF and Routing Policy
- Standard Firewall Policy

Each one-off script would have to re-invent parsing of the network configurations with which it would interact. This had the unhappy side effect that a single line of unexpected configuration on the network could cause any number of scripts to explode.

In a similar way each script had to re-invent interacting with various database APIs that manage the allocation of network resources.

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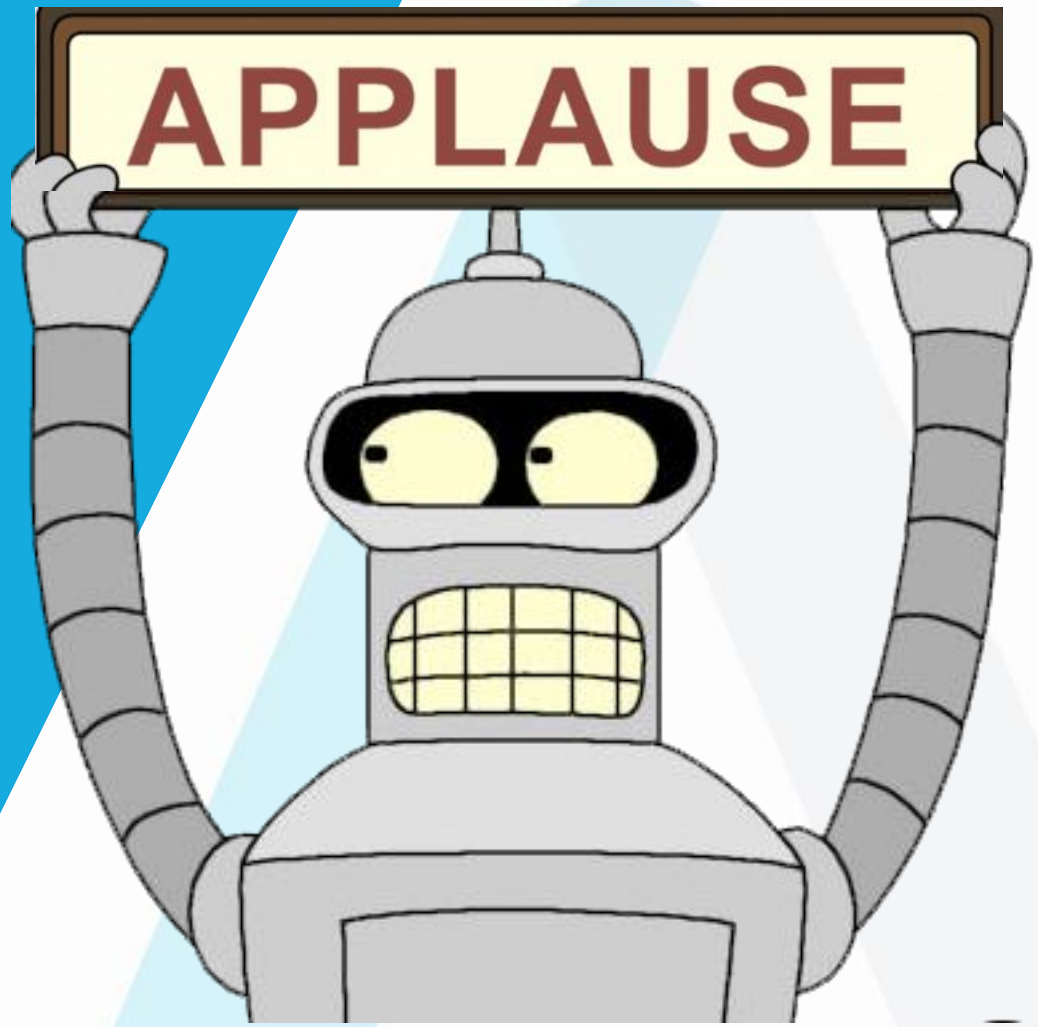
Introducing Bender

The REANNZ Network Automation Monorepo



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Network Automation

> 2019 - Present | Bender

The Bender network automation framework began as a mechanism for unifying network configuration parsing in a single reusable model.

Parsing of entire network configuration contributed greatly towards finding improper, unnecessary, or stale config on the network, further standardising network services and configuration templates.

It was further expanded to include the ability to make changes to a network device's configuration via various CLI tools and generate standard configuration via a generator library.

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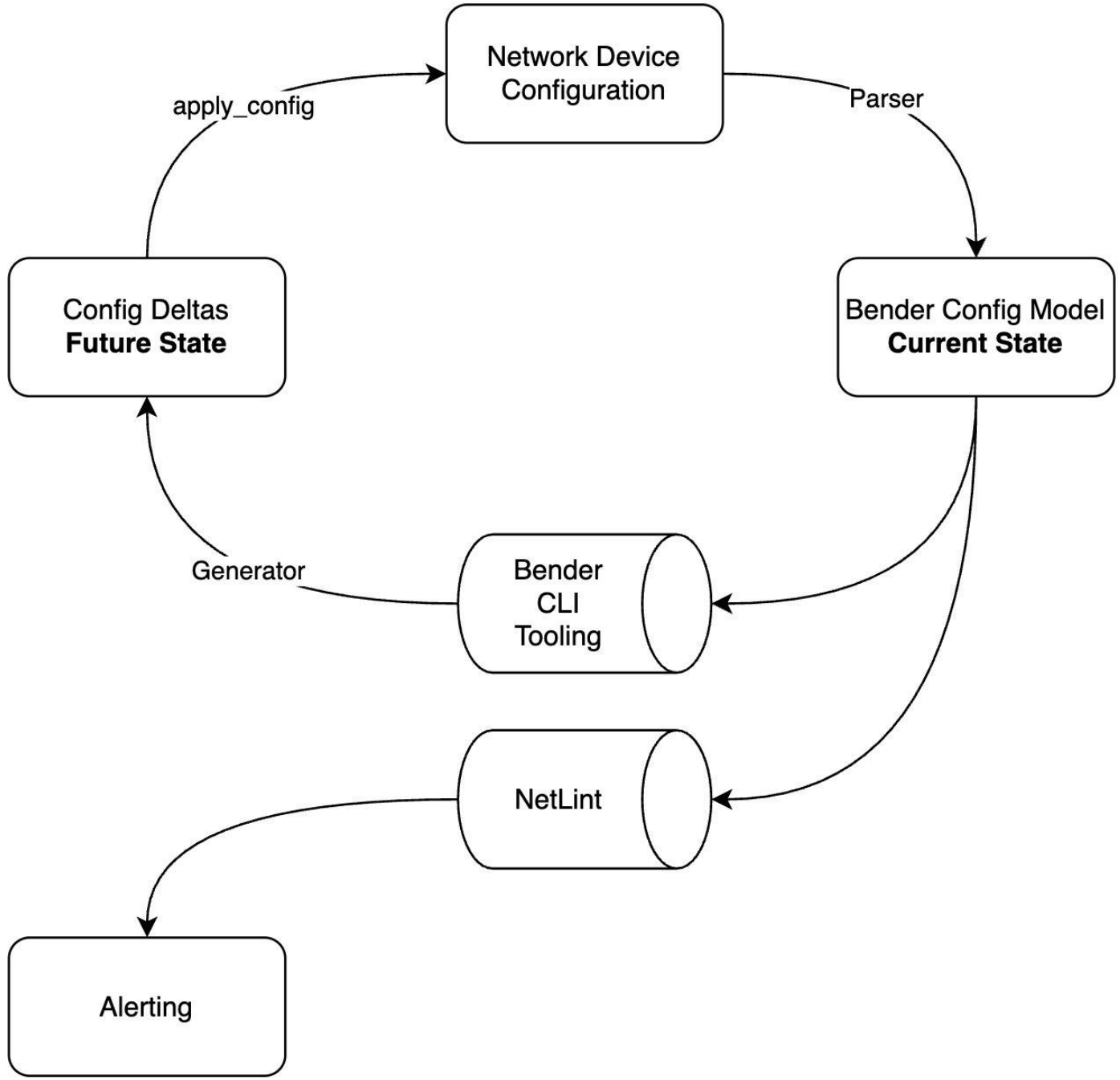
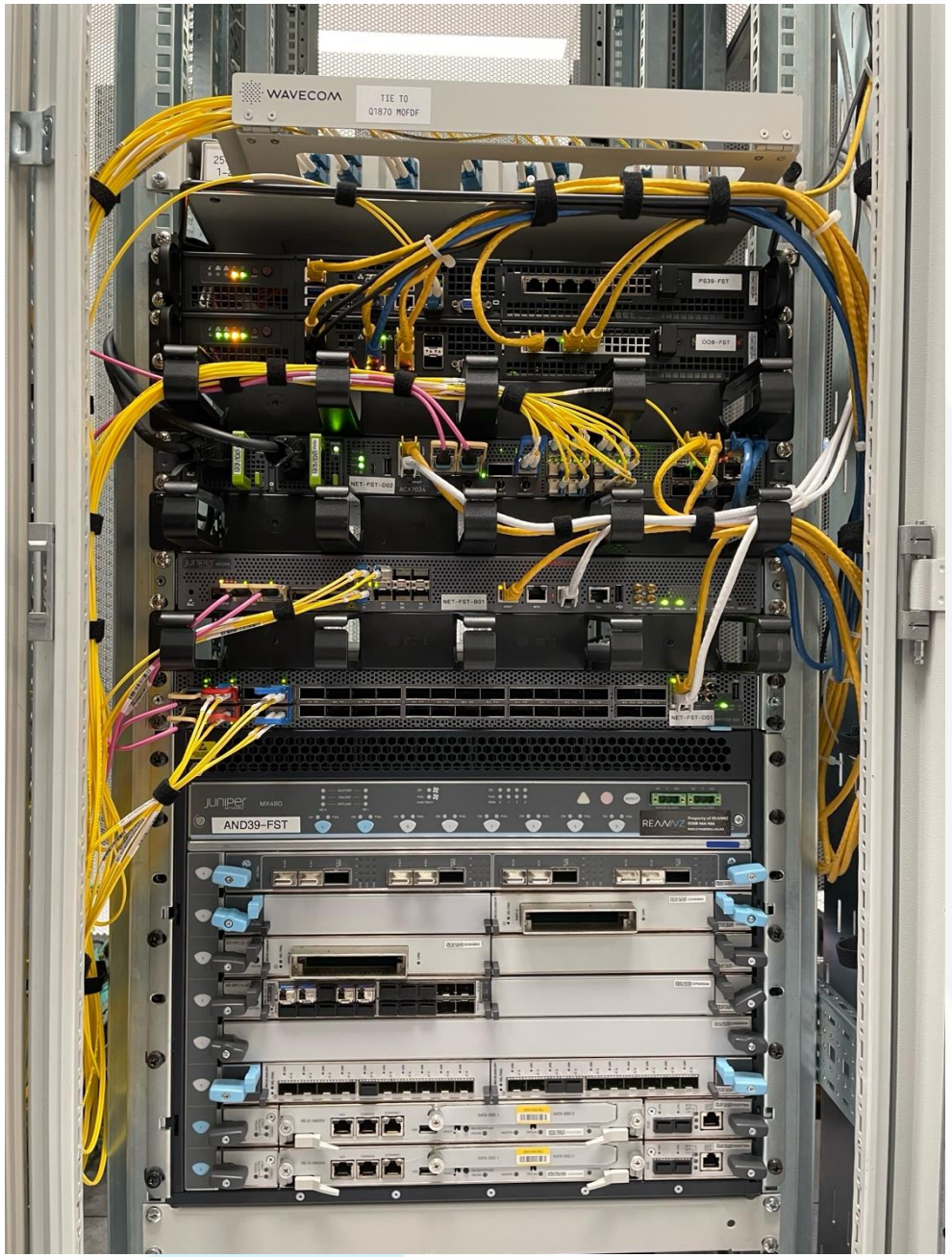

Network Device Configuration
Parser
Bender Config Model
Current State
Bender CLI Tooling
NetLint
Alerting
Generator
Config Deltas
Future State
apply_config

Hardware Refresh

Hardware Refresh

REANNZ


juniper
MX480
AND39-FST
REANNZ
S39-FST


WAVECOM
TIE TO
Q1870 MOFDF
juniper
MX480
AND39-FST
REANNZ

REANNZ

Deployment

- Configurations ~97% generated, reviewed by 2 engineers.
- 1 x engineer on-site, 1 x engineer leading the change remotely.
- 3-hour change window (typically 9pm – 11:59pm).
- Migrate 8 – 12 member handovers per night.

Problem

The main difficulty faced in such a project is ascertaining if a network service is functioning post-migration, and if not, was it functioning before the migration.

Monitoring cannot be relied upon for this:

> As currently implemented by REANNZ, monitoring cannot distinguish an existing service that is migrated onto new interface vs. a new service altogether.

> Monitoring lacks context – some things may evidence a fault when migrating services but also occur during normal operation.

Even basic handovers have enough complexity that it is difficult and time consuming to check all state and notice anything that's wrong.

REANNZ

State Check Tooling

The REANNZ network state check tooling attempts to automate gathering all state related to an interface pre- and post-migration, and present any changes back to the engineer to triage and action if necessary. This means the engineer's focus will be drawn specifically to services that are most likely to be broken.

What evidence are you looking for?

Interface

- Link state (Up/Down)
- MTU
- Throughput?
- Optical Information
  - RX optical level

VLAN

- MTU
- VLAN push/pop operation
- EVPN multi-homed status
  - (Forwarding/Blocking)
- Throughput?

BFD

- Session State (Up/Down/None)

BGP Handover

- Neighbours
  - State (Up/Down)
  - Number of Routes Received
  - Number of Routes Accepted
  - Number of Routes Advertised

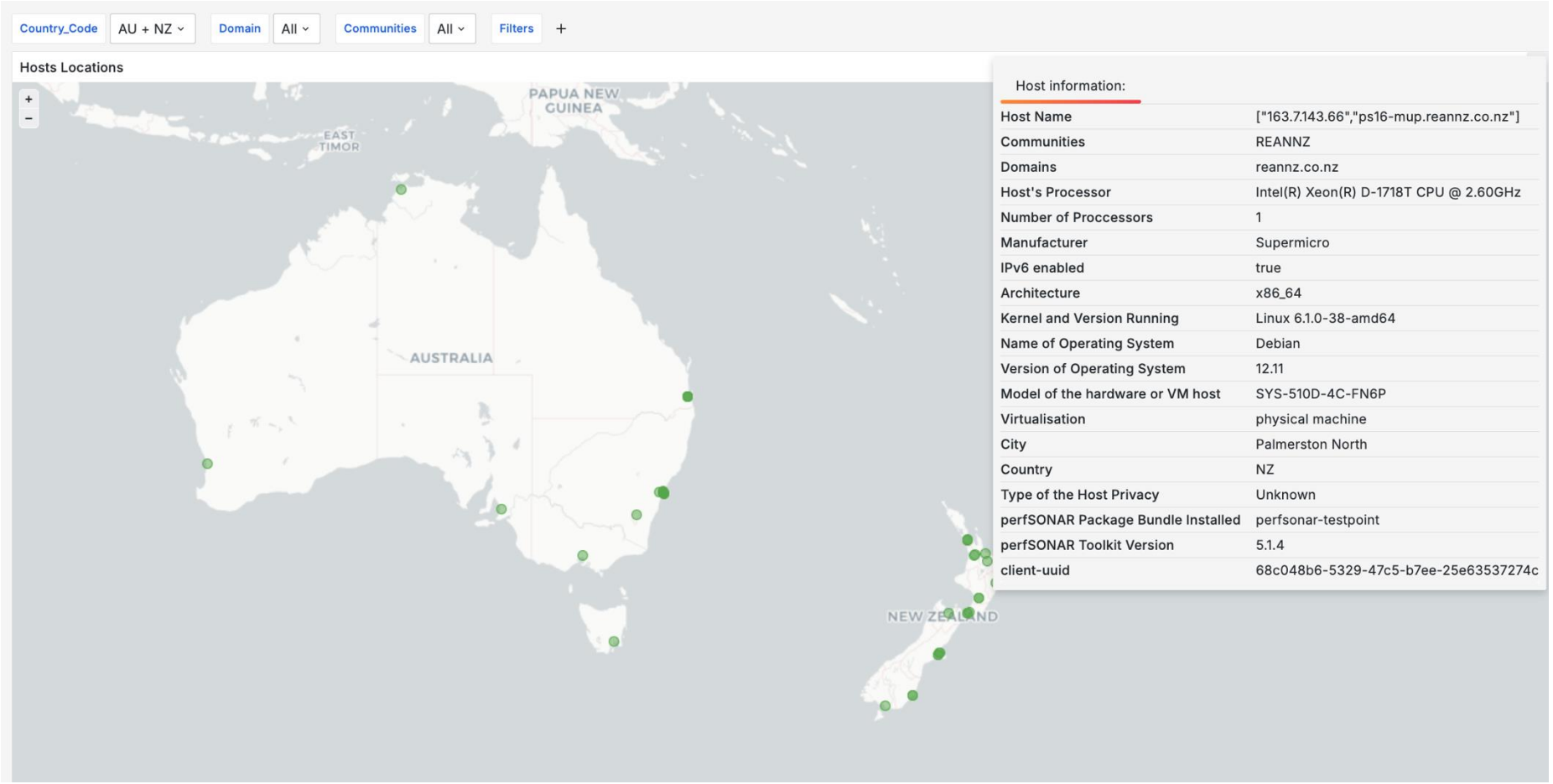
OSPF Handover

- Neighbours
  - State (Full/ExStart/etc.)

REANNZ

A Simple Test

A REANNZ perfSONAR node requires only an internet uplink for its network connectivity.



What is Moving?

```
migrations:
- after:
    host: net-mup-d01
    interface: et-0/0/8
    series: acx
  before:
    host: and16
    interface: xe-0/0/9
    series: mx
  id: '000'
  type: interface
- after:
    host: net-mup-d01
    interface: et-0/0/8
    series: acx
    vlan_id: 162
  before:
    host: and16
    interface: xe-0/0/9
    series: mx
    vlan_id: 162
  id: '001'
  type: vlan
```

REANNZ

What Information Do We Need?

```
and16>show interfaces xe-0/0/9.162 extensive
  Logical interface xe-0/0/9.162 (Index 568) (SNMP ifIndex 663) (Generation 377)
    Description: ps16-mup Internet
    Flags: Up SNMP-Traps 0x4000 VLAN-Tag [ 0x8100.162 ]  Encapsulation: ENET2
    Traffic statistics:
     Input  bytes  :          76714976903
     Output bytes  :          35737224035
     Input  packets:            436300434
     Output packets:            419958784
     IPv6 transit statistics:
     Input  bytes  :          72123522245
     Output bytes  :          34239482699
     Input  packets:            420510431
     Output packets:            402143542
    Local statistics:
     Input  bytes  :             25128792
```

```
Logical interface xe-0/0/9.162 (Index 568) (SNMP ifIndex 663)
  Description: ps16-mup Internet
  Flags: Up SNMP-Traps 0x4000 VLAN-Tag [ 0x8100.162 ]  Encapsulation: ENET2
  Input packets : 436300429
  Output packets: 419958780
  Protocol inet, MTU: 9000
  Max nh cache: 75000, New hold nh limit: 75000, Curr nh cnt: 1, Curr new hold cnt: 0, NH drop cnt: 0
    Flags: Sendbcast-pkt-to-re, User-MTU, Sample-input, Sample-output
    Addresses, Flags: Is-Preferred Is-Primary
      Destination: 163.7.143.64/30, Local: 163.7.143.65, Broadcast: 163.7.143.67
  Protocol inet6, MTU: 9000
  Max nh cache: 75000, New hold nh limit: 75000, Curr nh cnt: 2, Curr new hold cnt: 0, NH drop cnt: 0
    Flags: Is-Primary, User-MTU, Sample-input, Sample-output
    Addresses, Flags: Is-Default Is-Preferred Is-Primary
      Destination: 2404:138:143:64::/112, Local: 2404:138:143:64::1
    Addresses, Flags: Is-Preferred
      Destination: fe80::/64, Local: fe80::4271:8300:a2a3:3009
  Protocol multiservice, MTU: Unlimited
```

```
                                                                                240 bps
                                                                                  0 bps
                                                                                  0 pps
                                                                                  0 pps

                                                                                  0 bps
                                                                                  0 bps
                                                                                  0 pps
                                                                                  0 pps

                                                                  nh cnt: 1, Curr new hold cnt: 0, NH drop cnt: 0

                                                                  t, Sample-output


                                                                  65, Broadcast: 163.7.143.67, Generation: 235

                                                                  nh cnt: 2, Curr new hold cnt: 0, NH drop cnt: 0
    Flags: Is-Primary, User-MTU, Sample-input, Sample-output
    Input Filters: xe-0/0/9.162-inet6-i
    Addresses, Flags: Is-Default Is-Preferred Is-Primary
      Destination: 2404:138:143:64::/112, Local: 2404:138:143:64::1
  Generation: 237
    Addresses, Flags: Is-Preferred
      Destination: fe80::/64, Local: fe80::4271:8300:a2a3:3009
  Protocol multiservice, MTU: Unlimited, Generation: 239
  Generation: 553, Route table: 64
    Policer: Input: __default_arp_policer__
```

REANNZ

What Information Do We Need?

```
net-mup-d01>show interfaces diagnostics optics et-0/0/8
Physical interface: et-0/0/8
    Module temperature                      :  34 degrees C / 93 degrees F
    Module voltage                          :  3.348 V
    Module max power                        :  2 W
    Module temperature high alarm           :  Off
    Module temperature low alarm            :  Off
    Module temperature high warning         :  Off
    Module temperature low warning          :  Off
    Module voltage high alarm               :  Off
    Module voltage low alarm                :  Off
    Module voltage high warning             :  Off
    Module voltage low warning              :  Off
    Module temperature high alarm threshold :  80 degrees C / 176 degrees F
    Module temperature low alarm threshold  :  -10 degrees C / 14 degrees F
    Module temperature high warning threshold : 75 degrees C / 167 degrees F
```

```
net-mup-d01>show interfaces et-0/0/8.162 extensive
  Logical interface et-0/0/8.162 (Index 1426) (SNMP ifIndex 531) (Generation 609885357967)
    Description: ps16-mup Internet
    Flags: Up SNMP-Traps VLAN-Tag[ 0x8100.162 ]  In(pop) Out(push 0x8100.162)  Encapsulation: VLAN-VPLS DF
  Traffic statistics:
   Input  bytes  :          42317333220
   Output bytes  :          20718855347
   Input  packets:            200184663
   Output packets:            192869380
   Local statistics:
    Input  bytes  :                 2416
    Output bytes  :                    0
    Input  packets:                   26
    Output packets:                    0
   Transit statistics:
    Input  bytes  :          42317330804                30672 bps
    Output bytes  :          20718855347                14088 bps
    Input  packets:            200184637                   18 pps
    Output packets:            192869380                   18 pps
    Protocol ethernet-switching, MTU: 9192, Generation: 609885357984, Route table: 115, Mesh Group: __all_ces__, Next-hop: 9212
      Flags: Is-Primary
```

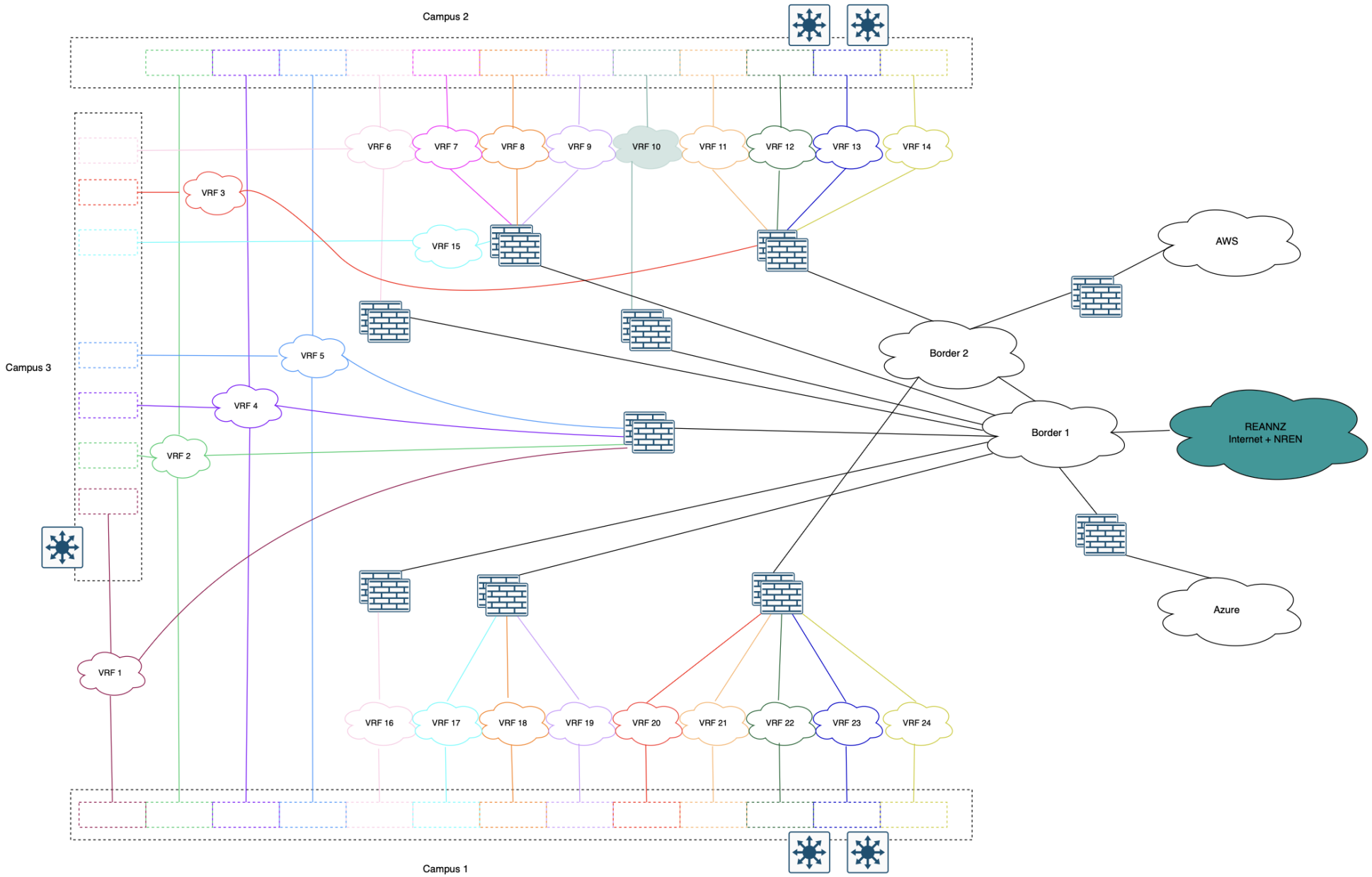
```
    Laser temperature high warning          :  Off
    Laser temperature low warning           :  Off
    Laser receiver power high alarm         :  Off
    Laser receiver power low alarm          :  Off
    Laser receiver power high warning       :  Off
    Laser receiver power low warning        :  Off
    Laser output power high alarm           :  Off
    Laser output power low alarm            :  Off
    Laser output power high warning         :  Off
    Laser output power low warning          :  Off
    Tx loss of signal functionality alarm   :  Off
    Rx loss of signal alarm                 :  Off
    Tx laser disabled alarm                 :  Off
```

REANNZ

Is this Service Working?

A Challenging Test

This is an anonymized recreation of a REANNZ member network's logical routing topology.



A Challenging Test

```
migrations:
- after:
    host: net-ttt-b01
    interface: xe-0/1/0
    series: mx
  before:
    host: and01
    interface: xe-0/0/2
    series: mx
  id: '000'
  type: interface
- after:
    host: net-ttt-b01
    interface: xe-0/1/0
    series: mx
    vlan_id: 1050
  before:
    host: and01
    interface: xe-0/0/2
    series: mx
    vlan_id: 1050
  id: '001'
  type: vlan
```

REANNZ

```
- after:
    host: net-ttt-b01
    interface: xe-0/1/0
    series: mx
    vlan_id: 1050
    vrf: ttt-border
  before:
    host: and01
    interface: xe-0/0/2
    s"before-and01-dump.txt" 51400L, 3538078B
    vlan_id: 1050
    "after-net-ttt-b01-dump.txt" 51005L, 3565122B
  id:
  type: vrf
- after:
    bgp_neighbour: 172.24.32.140
    host: net-ttt-b01
    series: mx
    vrf: ttt-border
  before:
    bgp_neighbour: 172.24.32.146
    host: and01
    series: mx
    vrf: ttt-border
```

Total 1525 lines!!!

```
- after:
    host: net-ttt-b01
    interface: xe-0/1/0
    series: mx
    vlan_id: 2501
  before:
    host: and01
    interface: xe-0/0/2
    series: mx
    vlan_id: 2501
    type: vlan
    evpn-2501
    host: net-ttt-b01
    interface: xe-0/1/0
    series: mx
    vlan_id: 2501
  before:
    evpn: evpn-2501
    host: and01
    interface: xe-0/0/2
    series: mx
    vlan_id: 2501
  id: 019
  type: evpn
```

```
- after:
    host: net-ttt-b01
    interface: xe-0/1/0
    series: mx
    vlan_id: 220
  before:
    host: and01
    interface: xe-0/0/2
    series: mx
    vlan_id: 220
  id: '025'
  type: vlan
- after:
    host: net-ttt-b01
    interface: xe-0/1/0
    series: mx
    vlan_id: 220
    vrf: ttt-tsg-ttt
  before:
    host: and01
    interface: xe-0/0/2
    series: mx
    vlan_id: 220
    vrf: ttt-tsg-ttt
  id: '026'
  type: vrf
- after:
    host: net-ttt-b01
    interface: xe-0/1/0
    series: mx
    vlan_id: 220
    vrf: ttt-tsg-ttt
  before:
    host: and01
    interface: xe-0/0/2
    series: mx
    vlan_id: 220
    vrf: ttt-tsg-ttt
  id: '027'
  type: ospf_neighbour
```

A Challenging Test

```
2025-08-03T18:37:12.571090Z [warning  ] Getting human-readable state for host net-ttt-b01, this may take several minutes [bender.cli.port_migration_state]

================================================================================
Vlan_State changed from (and01:xe-0/0/2.220) to (net-ttt-b01:xe-0/1/0.220):
- output_packets: 1839
+ output_packets: 382
================================================================================

================================================================================
Vlan_State changed from (and01:xe-0/0/2.226) to (net-ttt-b01:xe-0/1/0.226):
- input_packets: 262
+ input_packets: 4358
================================================================================

================================================================================
Vlan_State changed from (and01:xe-0/0/2.275) to (net-ttt-b01:xe-0/1/0.275):
- input_packets: 9
+ input_packets: 0
- output_packets: 10
+ output_packets: 0
================================================================================

================================================================================
Vlan_State changed from (and01:xe-0/0/2.211) to (net-ttt-b01:xe-0/1/0.211):
- output_packets: 0
+ output_packets: 2
================================================================================

================================================================================
Vrf_State changed from (and01:ttt-mgmt) to (net-ttt-b01:ttt-mgmt):
- rt_entry:172.24.128.97/32, next_hop:Remote
+ rt_entry:172.24.128.109/32, next_hop:Remote
================================================================================

================================================================================
Vlan_State changed from (and01:xe-0/0/2.228) to (net-ttt-b01:xe-0/1/0.228):
- input_packets: 1876
+ input_packets: 464
================================================================================
```

REANNZ

Is It Necessary?

```
================================================================================
Interface_State changed from (and16:xe-0/0/9) to (net-mup-d01:et-0/0/8):
- oper_status: up
+ oper_status: down
================================================================================
```

```
================================================================================
Bgp_Handover_State changed from (and01:172.24.10.40) to (net-ttt-d02:172.24.10.40):
- state: Established
+ state: Connect
================================================================================
```

```
================================================================================
Vlan_State changed from (and17:ge-2/0/1.2106) to (net-avl-d02:et-0/0/16.2106):
- input_packets: 425
+ input_packets: 0
================================================================================
```

```
================================================================================
Bgp_Handover_State changed from (and01:172.24.52.9) to (net-ttt-b01:172.24.52.9):
- routes_received: 359
+ routes_accepted: 355
================================================================================
```

```
================================================================================
Interface_State changed from (and01:ge-2/0/1) to (net-ttt-b01:xe-0/1/1):
- rx_optical_level: -9.7
+ rx_optical_level: -15.08
================================================================================
```

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Tooling on Trial

Incidents:

1.) ‘Independent-domain’ BGP attribute omitted from private WAN VRF causing BGP loop detection to suppress active routes.

> Verdict: This occurred during the first migration completed by REANNZ as a part of this project and was completed prior to the tooling being deployed. Tooling innocent.

2.) MTU omitted with the creation of REANNZ backhaul circuit causing localised isolation to a remote region.

> Verdict: Tooling was available with this configuration correctly implemented in generator but was not used. Tooling innocent.

3.) BGP configuration omitted for long-lined internet service downstream of device.

> Verdict: No tooling, terrible engineer.

Ultimately if we are to commit resources into any project it must be able to demonstrate a positive outcome for the users of the service.

In this instance that is measurable by the unplanned network disruption caused or averted, so let’s start the inquiry:

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Any limitations still?

- Difficulty Enforcing Standard Architectures
  - > The tooling only knows what it knows. Missing or additional configurations appearing on the network can fly under the radar if it is not anticipated.

- Network as the Source of Truth
  - > Service-enriching metadata needs encoding in network configurations, which does not scale well.
  - > Resource management difficult and unreliable when there is no enforced synchronization with inventory databases.

- Network-centric, not Service-centric
  - > Doesn’t offer a good story for REANNZ members –engineers convert user requirements to network configurations but the service context they have is mostly lost when the configurations are deployed.

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Where to Next?

An automation platform is being developed inside REANNZ fed from a database of *intent*.

An orchestration layer will be present to manage the lifecycle of a service from deployment through retirement, enforcing configuration templates as it passes service information to a device configuration layer.

Custom configuration will continue to be allowed, but it will be managed within the orchestrator for visibility.

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Thank you

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