Emergency Telecommunications at Community Emergency Hubs – Summary of the Starlink tests

FINAL

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This report summarizes the tests carried out with Starlink systems in the framework of the project "Emergency Telecommunications at Community Emergency Hubs", recipient of Civil Defence Emergency Management (CDEM) Resilience Fund grant administered by the National Emergency Management Agency (NEMA). The contributors to this report are Eric Sauvage (University of Auckland) and Dr Richard Mowll (WREMO).

Executive Summary

This reports first details the different options regarding Starlink units/plans in New Zealand. The approach and results of the different testing sessions are then exposed. They aim at understanding better the performance of Starlink units, the requirements for set-up, the limitations, and can be seen as a baseline for further testing of this technology.

The Starlink tests were carried out using units owned by the emergency management sector. They involved three different types of dishes namely a standard first-generation unit, a standard second-generation unit, and a high-performance unit. These units were running on different services plans (Standard and Mobile Priority), and the testing sessions were held in Wellington and Auckland.

The main learnings can be summarized as follows:

- The Starlink Standard systems, tested in Wellington, typically had a download speed of 150 Mbps and upload speed of 25 Mbps. A total of 11 devices were connected to the router. In the case of the Starlink high performance system, more than 20 devices could simultaneously access the internet, without experiencing additional delays due to the high number of connections.
- Two different power supplies were tested, the first one on the mains power and the second one with a car battery (taken from a Toyota Corolla, 2016) fitted with an inverter. When relying on the car battery, it is recommended to plug the inverter directly on the battery rather than on the cigarette lighter, as the internal system of the car may not be designed to support a power requirement of a high-performance dish.
- The power usages are typically around 70W for Starlink standard systems, and 110W for Starlink high performance. Under such conditions, a Starlink standard system is likely to be functional for 7 hours, and a Starlink high performance system for 4 and a half hours with a battery of similar specifications.
- Weather variations (e.g. clear/dry day vs rainy/overcast day) did not significantly influence data speeds and power usage of Starlink systems during the tests.
- In the case of the high-performance dish, finding a location that minimizes the obstruction of the view of the sky (and therefore line of sight to satellites) is a key aspect for avoiding interruptions. Setting such a location may be challenging in urban areas and, prior to a potential deployment during a disaster, it is recommended to identify some suitable spots.
- The connection to the internet via Starlink allows Wi-Fi calling from devices connected to the unit. The tests carried out involved mobile phones operating on the three main carriers in New Zealand (One, Spark, 2Degrees). All could make and receive calls to or from another phone connected to Wi-Fi or to a cellular network. Calls to landline numbers have also been tested and tend to validate that dialling 111 is possible via Wi-Fi calling.
- The Starlink app was used to run these tests. If a Starlink system had to quickly be deployed in a CEH following an emergency, it would be an advantage to have the app already installed on at least one mobile phone within the community. The app monitors the download, upload speeds and latency of the connection, and helps finding the optimal location for the dish, in particular for the high-performance system.

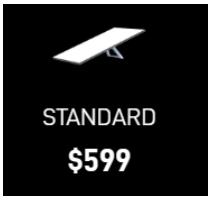
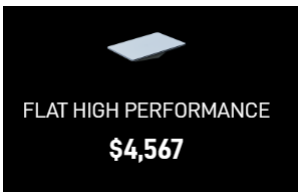
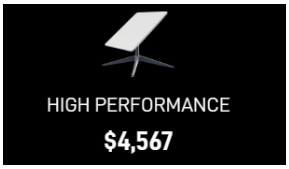
Further observations and learnings from tests with the Starlink High Performance unit are included on page 14.

Starlink in New Zealand

Table 1: Starlink service plans in New Zealand (https://www.starlink.com/nz/service-plans/all, May 2024)

Personal – households	**Standard / Residential** Unlimited high-speed, low-latency internet	Standard	159 NZD/month
		Deprioritized	79 NZD/month
Personal - RVs, nomads, and campers	**Mobile / Roam** Unlimited Mobile Data inland, Portability, Pause Service <10 mph (16 kph) in-motion	Mobile - regional	199 NZD/month
		Mobile – global	340 NZD/month
Personal / Business - maritime, emergency response, and mobile businesses	**Boats / Maritime / Land Mobility** All The Features of Mobile - Global Service, In-motion + Ocean Use, Network Priority, Priority Support	Mobile Priority – 50 GB	457 NZD/month
		Mobile Priority – 1 TB	1700 NZD/month
		Mobile Priority – 5 TB	8520 NZD/month
Business - businesses and high demand users	**Priority / Fixed site** Unlimited Standard Data, Public IP, Network Priority, Priority Support	Priority – 40 GB	196 NZD/ month
		Priority – 1 TB	426 NZD/month
		Priority – 2 TB	840 NZD/month
		Priority – 6 TB	2507 NZD/month

Table 2: Starlink service plans and satellite dishes (https://www.starlink.com/nz/service-plans/all, May 2024)

Standard and Mobile	
Mobile Priority	
Priority	

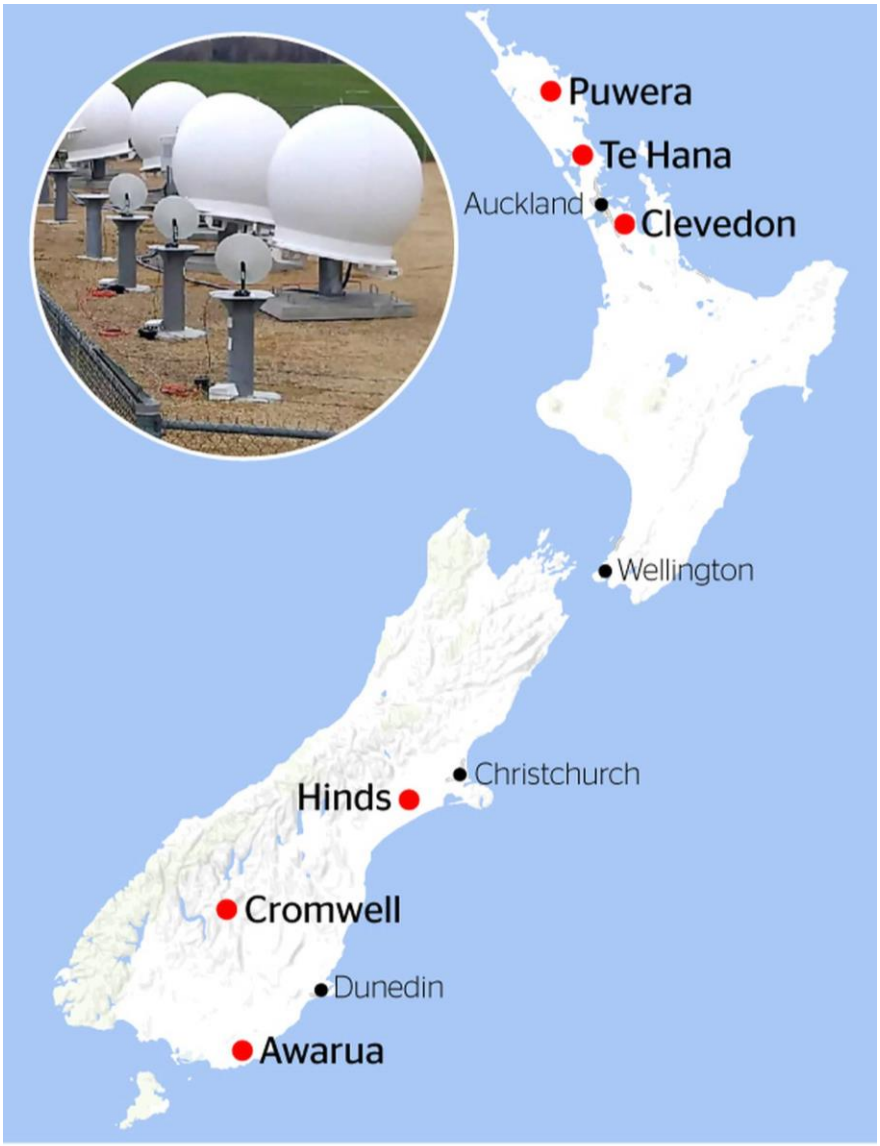


Figure 1: Starlink ground stations locations in New Zealand

Approach for the tests

For all tests, at least three devices (two mobile phones and one laptop) were connected to the Wi-Fi network set-up by the Starlink units.

Most of the testing sessions assessed the data speeds and other parameters associated with the connection (download, upload speeds and latency) over 30 minutes or more, via the Starlink app directly or the Chorus website. The aspects related to power usage and autonomy on car battery were dealt with during the last tests.

Table 3: Details of the tests

Testing session	Devices	Scope
Test 1 *(Wellington)*	- Starlink standard second generation unit - 350W pure sine wave inverter - Car battery - Mobile phone with the Starlink app installed - Other mobile phones and laptops	- Speed test, when the unit is powered by the mains - Autonomy on a car battery for 15 minutes
Test 2 *(Wellington)*	- Starlink standard second generation unit - Mobile phone with the Starlink app installed - Other mobile phones and laptop	- Speed test, when the unit is powered by the mains
Test 3 *(Wellington)*	- Starlink standard first generation unit - Mobile phone with the Starlink app installed - Other mobile phones and laptop	- Speed test, when the unit is powered by the mains
Test 4 *(Auckland)*	- Starlink high performance unit - Peplink router - Mobile phones and laptops	- Speed test, when the unit is powered by the mains
Test 5 *(Auckland)*	- Starlink high performance unit - Peplink router - Power meter - Mobile phones and laptop	- Speed test, when the unit is powered by the mains - Power measurement
Test 6 *(Auckland)*	- Starlink high performance unit - Peplink router - Power meter - Mobile phone with the Starlink app installed - Other mobiles phones and laptop	- Optimal orientation of the dish - Speed test, when the unit is powered by the mains - Power measurement
Test 7 *(Auckland)*	- Starlink high performance unit - Peplink router	- Tests related to the number of connections and type of communications allowed by the unit
Test 8 *(Auckland)*	- Starlink priority mobile unit - Peplink router - 500W pure sine wave inverter - Power meter - Car battery - Mobile phones and laptop	- Speedtest when the unit is powered by a car battery - Power measurement
Test 9 *(Auckland)*	- Starlink priority mobile unit - Peplink router - 500W pure sine wave inverter - Power meter - Car battery - Mobile phones and laptop	- Test in a place free of obstructions - Speedtest when the unit is powered by a car battery - Power measurement
Test 10 *(Auckland)*	- Starlink high performance unit - 500 W pure sine wave inverter - Power meter - Car battery - Mobile phones and laptop	- Autonomy on a car battery - Speedtest when the unit is powered by a car battery - Power measurement

Set-ups and results

Tests 1, 2 and 3 on the Starlink standard units

The tests were run in WREMO in May 2024. The connection provided by the unit proved to be stable enough to allow Wi-Fi calling, which was in practise tested after switching the mobile phones in flight mode. Up to 11 devices could connect and access the internet, however they experienced delays when trying to access links with high data speed requirements, such as HD videos.

A quick set-up was made up with a car battery of a 60 Ah capacity (from a Toyota Corolla), with connection to the inverter via the cigarette ligther or directly via external cables. The car battery could provide power to the Starlink unit. Its autonomy is the scope of further experiments carried out in Test 10.

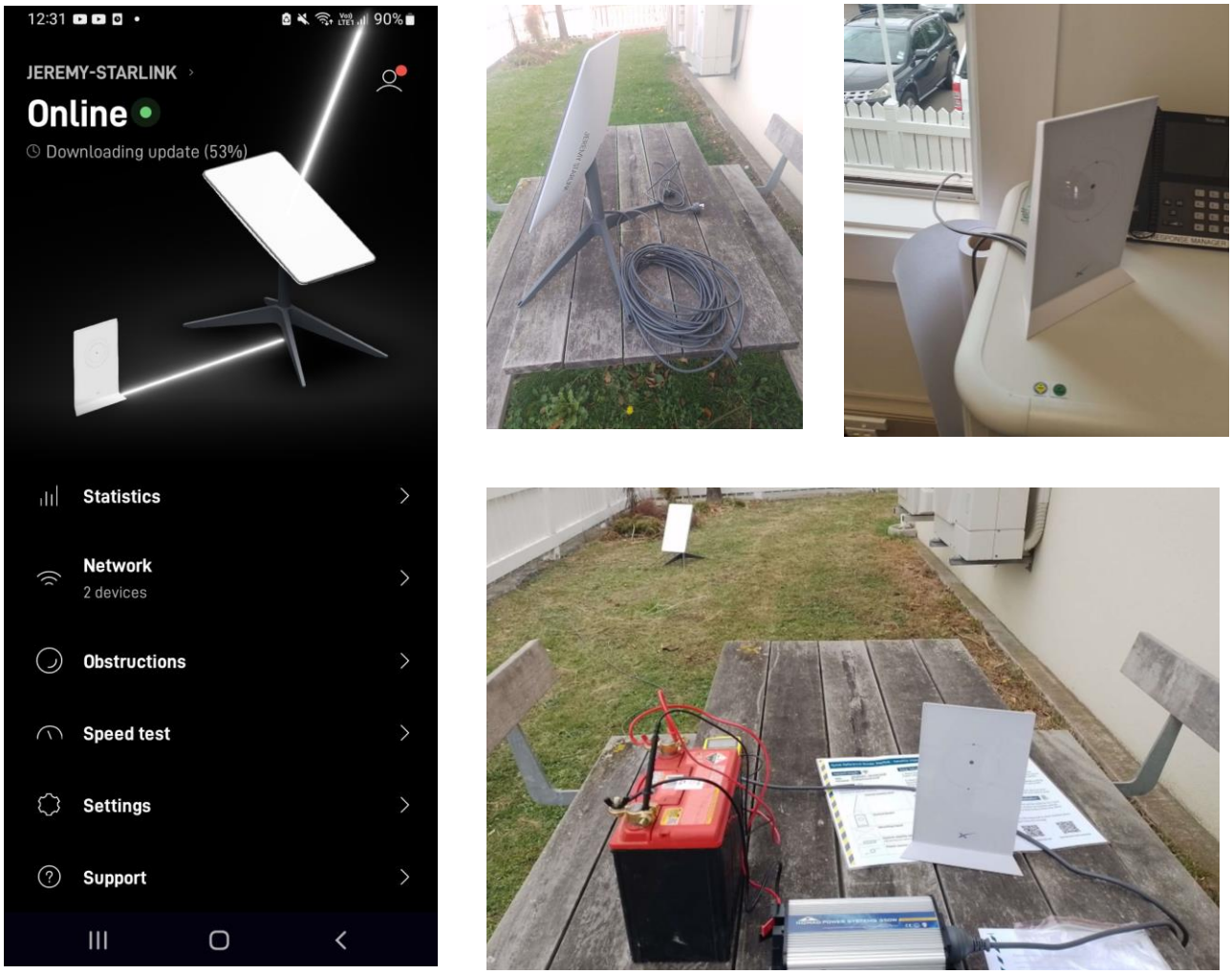


Figure 2: Set-up for the test with the Starlink standard second generation unit (Test 1)

Table 4: Starlink speed test with a strandard second generation unit (Test 2)

Time	Starlink speed test		
	Download	Upload	Latency
12:45	104	26	28
12:48	165	24	28
12:50	179	39	32
12:53	140	36	28

12:55	143	29	28
12:57	118	32	34
12:58	175	33	28
13:00	156	17.3	31
13:02	130	29	28
13:04	165	24	27
13:06	123	30	**115**
13:09	156	17.2	32
13:11	142	23	28
13:13	182	39	28
13:15	157	24	33

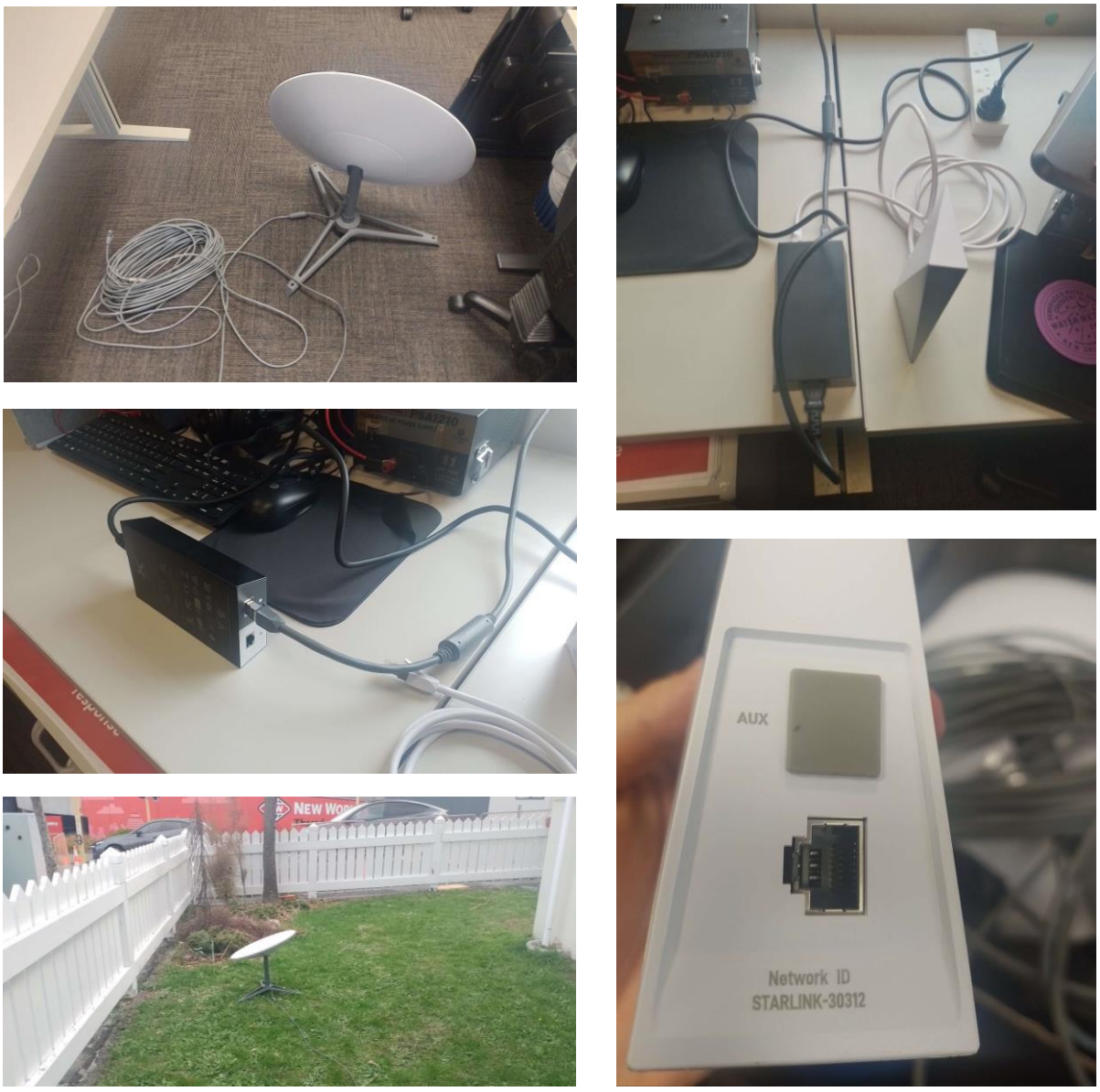


Figure 3: Set-up for the tests with the Starlink standard first generation unit (Test 3)

Table 5: Starlink speed test with a standard first generation unit (Test 3)

Time	Starlink speed test			Time	Starlink advanced test			
	Download	Upload	Latency		Router to internet		Device to router	
					Download	Upload	Download	Upload
13:46	31	14.8	45	13:50	189	23	26	22
13:53	36	17	33	13:54	215	37	23	14.6
13:55	29	18.7	31	13:57	212	32	24	7.4
13:59	39	19.3	33	14:00	227	31	20	13.7
14:04	35	13.9	35	14:05	182	37	31	22
14:08	30	14	30	14:09	203	35	27	20
14:12	23	17.2	38	14:13	204	29	28	22
14:15	38	16.8	31	14:16	209	19.1	30	16.5
14:19	32	16.7	28	14:20	170	25	36	38
14:23	28	18.3	29	14:23	169	18.2	26	23
14:25	45	16.2	39	14:26	194	22	32	32
14:28	27	14	32	14:29	220	29	37	25
14:31	41	8.5	41	14:32	174	31	34	21
14:35	27	23	33	14:36	151	21	30	24
14:38	23	12.6	33	14:39	207	24	27	22
14:41	29	13.7	36	14:42	196	21	23	26
14:44	25	18.5	35	14:45	171	30	26	23

Test 4 to 6 on the Starlink high performance unit

The tests were run in Auckland at the beginning of June. The output of Starlink is directly connected to a peplink router, which can perform content filtering and increase Wi-Fi coverage. This router was previously configured by NEMA and was provided as part of the Starlink unit.

Mobile phones and laptop connect to this peplink router the same way as they would with any Wi-Fi network, and there is no need to have a specific mobile phone with the Starlink app installed.

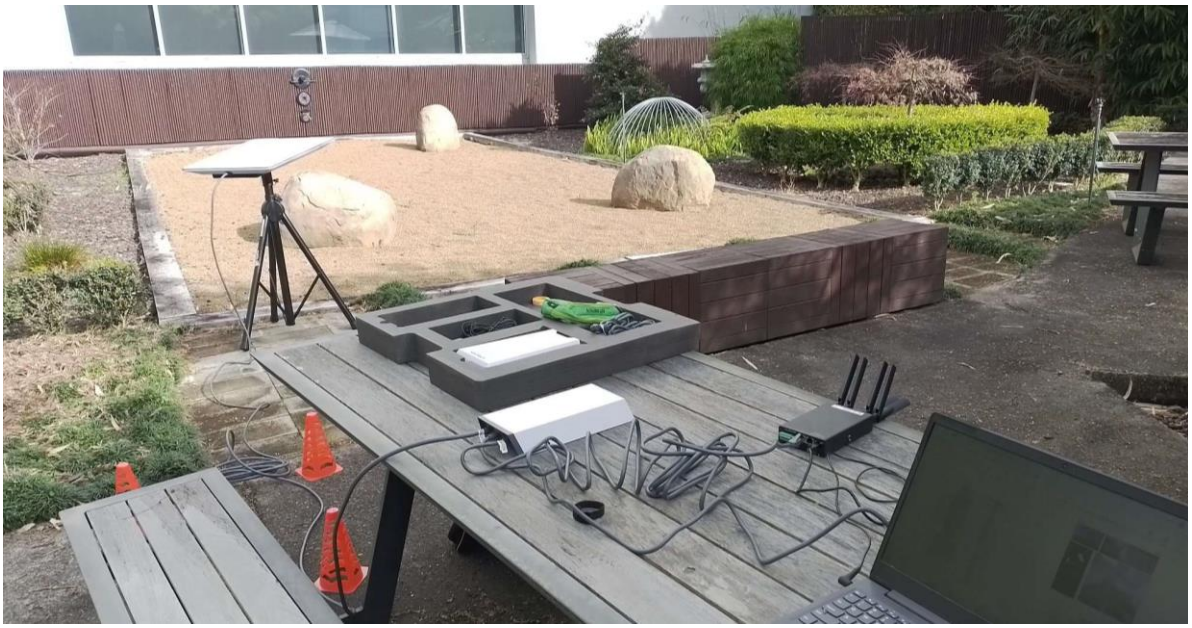


Figure 4: Set-up for the tests with Starlink high performance unit (Test 4)

Table 6: Starlink speed test with a high performancet (Test 4)

Time	**Chorus speed test**			
	Ping	Jitter	Download	Upload
12:56	24	6	242	23.5
12:59	28	4	260	24
13:02	25	4	222	29
13:05	31	11	278	37
13:08	29	3	194	26
13:11	24	5	254	24.7
13:14	27	5	58	17.7
13:17	29	17	174.6	14
13:20	19	6	223	28.5
13:23	22	6	189.7	20.7
13:26	27	7	131	25.8
13:29	25	54	249.5	23.6
13:32	25	6	236.9	6.1
13:35	23	1	303.5	37.3
13:38	23	3	197	15.2
13:40	27	5	208	20
13:43	30	3	277	12.8
13:46	26	4	192	22
13:49	28	5	205.8	8.1
13:52	25	13	235	22.4

For this set-up, the download and upload speeds are higher than for a standard unit. Contrary to a standard dish, the high performance dish doesn't have a rotor to find the optimal position for finding the satellites, and it probably explains the frequent interruptions of connection to the internet that the devices experienced.

The set-up for Test 5 is similar, with a power meter. The power usage peaks at 200W at the time of interruptions (typically for 15s every 4 to 7 minutes on the day of the test) and lies between 70W and 130W otherwise when the internet connection is there.

Figure 5: Set-up for the tests with the Starlink high performance unit, with power usage measurement (Test 5)

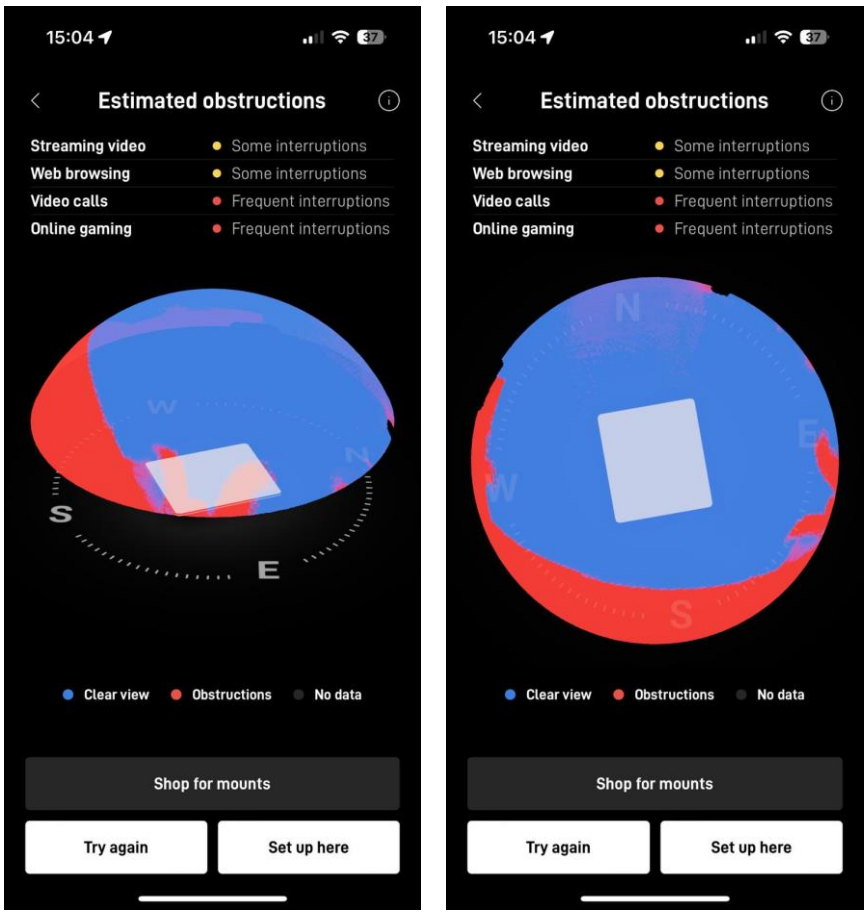


Figure 6: Starlink app for finding the optimal orientation of the high performance dish (Test 6)

For Test 6, the Starlink app was used from another mobile phone which has the sensors to scan the sky. It assessed the obstructions and helped finding the optimal orientation for the dish. Similar features and measurements (regular interruptions and power usage peaks at 200W) were observed.

Test 7 on the Starlink high performance unit

This session focused on the number of devices that could be simulateneously connected to the Starlink unit, the type and limitations of the connectivity that we could expect in a CEH.

The original idea consists of finding the maximum number of connections to the Starlink unit, considering different types of communication (video, social media, voice calls, texts) and two types of devices, laptops and mobile phones, that have different data demands.

Table 7: Communications, applications, and their typical speeds

Application	Bandwidth (kbps)
Wi-Fi-calling	120
Email	1,000
Music streaming	2,000
Web browsing (general)	3,000
Social media	5,000
Online gaming	5,000
Video conferencing	5,000
Video streaming	5,000
4K video streaming	15,000
WhatsApp voice calls	7 to 12.5
Skype calls	15
Messenger voice calls	5.5 to 12.5
WhatsApp video calls	83
Messenger video calls	80 to 250
WhatsApp chat	1*
Messenger chat	0.7*
Facebook app	25
Video resolution (SD144p)	500
Video resolution (SD240p)	500
Video resolution (SD360p)	700
Video resolution (SD480p)	1100
Video resolution (HD720p)	2,500
Video resolution (HD1080p)	5,000
Video resolution (4K, 2160p)	20,000
Video resolution (8K, 4320p)	100,000

* Assuming 30 kB per chat, and a message sent every 30s

The dish was placed at the same location as in the previous session. The connection parameters (latency, jitter, download and upload speeds) were not monitored. The power usage was regularly checked and proved to be consistent with the previous tests (from 70 to 110W when the internet was there, around 200W when experiencing interruptions). Participants connected their devices to the Wi-Fi network associated to the Starlink unit, and the mobile phones were swiched to flight mode.

10 participants took part in the tests. In total, a maximum of 22 devices were connected: 13 mobiles phones, 5 laptops, 1 notebook, 1 tablet, 1 steam deck and 1 watch.

Connectivity tests for all devices

Web browsing: check the following links: https://www.chorus.co.nz/

https://www.chorus.co.nz/speed-test

https://www.civildefence.govt.nz/

https://www.wremo.nz/

2 – Social media: check the following links: https://www.facebook.com/NZCivilDefence/

https://www.facebook.com/WREMOnz/

3 – Video: check the following link: https://www.youtube.com/watch?v=A6k8WM5fOGc

+ potentially Netflix, online gaming,…

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4 – Chat via apps (WhatsApp, Messenger, Skype)

5 – Sending pictures/videos over apps (WhatsApp, Messenger, Skype): is there any difference with other types of connections (regarding delay)?

6 – Voice calls over apps (WhatsApp, Messenger, Skype) for at least 1 minute: what are the types/durations of interruptions?

7 - Video calls over apps (WhatsApp, Messenger, Skype) for at least 1 minute: what are the types/durations of interruptions?

Test for mobile phones only

WiFi calling option: from Wi-Fi to Wi-Fi (both phones in flight mode, Wi-Fi calling activated)
from Wi-Fi to cellular (one phone in flight mode, Wi-Fi calling activated)
from Wi-Fi to the landline (one phone in flight mode, Wi-Fi calling activated)

8 – WiFi calling (calls for at least 1 minute)

- Configuration Wi-Fi to Wi-Fi to get the maximum number of connections
- Configuration Wi-Fi to cellular to have an idea regarding the interruptions

Figure 7: Form associated with Test 7

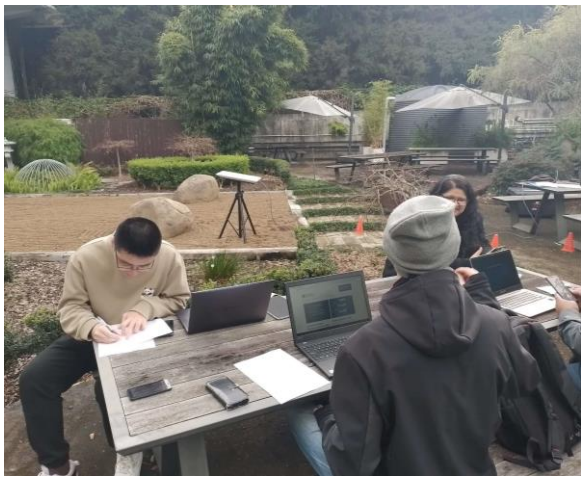

Figure 8: Set-up for Test 7

Table 8: Devices involved in Test 7

Mobile phones	Samsung A03 Alcatel Samsung A35 Huawei Iphone 5 Samsung S23 Google Pixel 7a Huawei P60 Iphone 13 Pro max Samsung OPPOF9 Pixel 8 Pro Xiaomi Redmi
Laptops	Lenovo 82C3 Lenovo L590 Acer Macbook Air M1 (2022) ASUS Zenbook V410
Notebook	Huawei notebook 16
Tablet	Huawei notepad 11 (2023)

Observations and learnings from tests

- The increase of the number of connected devices didn't have an influence on the power usage. Video streams were functional for all participants, and the increase of demand and video download didn't increase the power usage. The outages experienced by the participants were related to the interruption of signal out of the peplink (probably due to a loss of connectivity to the satellite) rather than to the increase of data demand from other devices
- A few websites were not reachable by most of the participants: only 4 out of 22 devices could connect to the Chorus and WREMO websites. The NEMA website and the Facebook pages could be reached by almost all devices.

- The communication via messages and photo sharing over mobile phones proved to be functional, however some delay was sometimes reported. For 2 participants, the desktop version of WhatsApp could not work, although the internet connection was fine. One of them could successfully make a video call via Messenger.
- Video and voice calls proved to be more challenging, due to the interruption of internet connectivity and a weak signal. When possible, the quality of video and voice calls was high, with no delay. In the event of interruption of the internet, the WhatsApp calls maintain and then resume the call when the connectivity returns.
- Wi-Fi calling; the session proved to be an interesting way to teach participants about the feature. Two mobile phones could not find the setting to activate it. When the Wi-Fi calling option was on, a call between two mobile phones connected to this network was not possible, probably because of the connection instability. A call to a landline number over Wi-Fi calling could be done for 5 minutes without interruption. The other calls to a mobile phone connected to the cellular network could also be initiated. However, in the event of interruption, the call could not resume properly, and the phone number had to be dialed again to communicate.

Test 8, 9, 10 on the Starlink high performance unit

These tests considered car battery and inverter to power the unit. The battery, new, was fully charged and has a capacity of 45 Ah. The inverter is a 500W pure sine wave.

Tests 8 and 10 were held in the same location in Auckland as Tests 4 to 7 and the only difference lied in the type of power supply. They show the same results regarding the wattage required for the unit and connectivity/interruptions.

Figure 9: Set-up for Test 8, with battery/inverter as power supply

Test 9 was carried in a different location in Auckland, in a park with very little obstructions of the view of the sky. The main concern was to optimize the field of view for the dish and to see the consequences on interruptions and power usage.

In such conditions, two power demands of 200W peaks lasting less than a second were observed during the 30 minutes of tests. The other values of power were the rest of the time between 80W and 130W. The battery voltage was all test long around 11.86V.

All values of download speeds were much lower (around 55 Mbps) than on the previous site, the upload speed being the same (around 20 Mbps).

Figure 10: Set-up for Test 9, with battery/inverter as power supply

Test 10 aimed at determining the amount of time the car battery can power the Starlink unit. The car battery was fully charged at the beginning of the test, which was run in the same location as Test 8 and other previous tests.

Figure 11: Set-up for Test 10

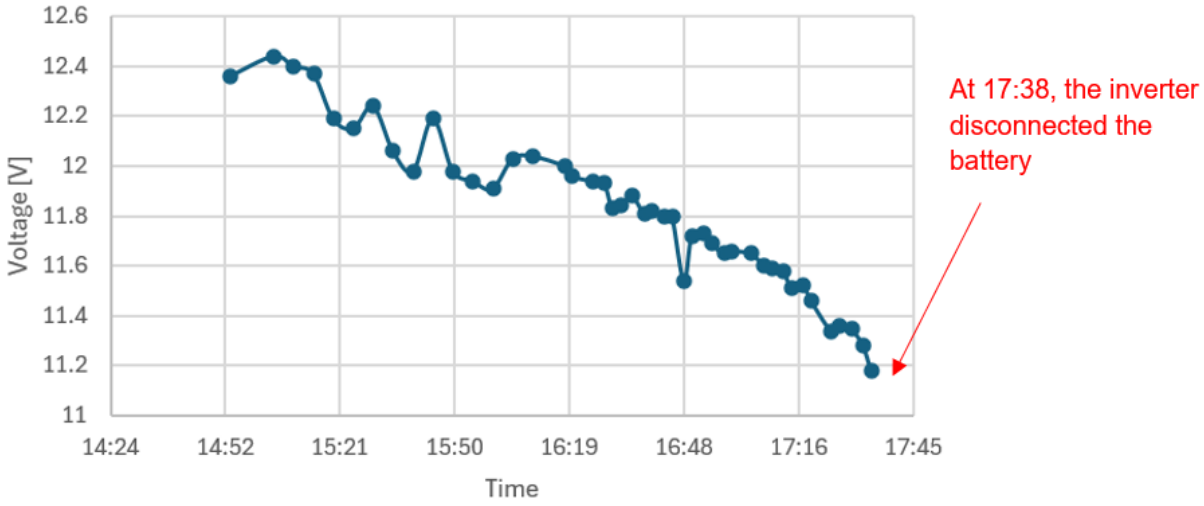

Figure 12: Evolution of voltage for Test 10

Comparison with theoretical values

- Battery voltage: 12V
- Battery capacity: 45 Ah
- Inverter efficiency: 90%
- Battery depth of discharge (assumed): 80%
- Power consumption of the Starlink: 110W on average, with regular peaks at 200W

With 110W of power consumption, the system can operate up to 12x45x0.8/(110/0.9) ≈ 3.5 hours before we need to recharge the battery.

With 200W of power consumption, the system can operate up to 12x45x0.8/(200/0.9) ≈ 2 hours before we need to recharge the battery.

In practice, the total time for connection during the test was 2h44.

Table 9: Battery autonomy depending on power requirements

Power \ Capacity	45 Ah	52 Ah	60 Ah	100 Ah
70 W	5.5h	6.5h	7.5h	12h
90 W	4.5h	5h	5.5h	9.5h
110 W	3.5h	4h	4.5h	7.5h
130 W	3h	3.5h	4h	6.5h
150 W	2.5h	3h	3.5h	5.5h
200 W	2h	2h	2.5h	4.5h