Sky Muster Plus Performance Report.

Abstract. It has been demonstrated that telehealth can be successfully implemented via high-quality (mining-grade), expensive satellite internet. However, the lack of adequate and affordable internet remains a barrier to telehealth. This research aimed to determine if the **NBN™** Sky Muster™ Plus satellite service would be adequate for telehealth in remote areas. Consumer grade Sky Muster™ Plus services were installed at a rural property approximately 35 kms south of Darwin. The area is subject to severe weather events and cyclones in the wet season. The quality (ping (latency), download and upload speeds) were monitored during the wet season at different times of the day and night including throughout moderate weather events. The Ookla speed test was used to monitor internet quality. It is important to note the assured rate for Sky Muster Plus is 25 mbps down and 5 mbps up. Performance in light weather seemed reasonably consistent with the mean download speed of 29.02 mbps and the mean upload speed of 8.82 mbps, with an average ping of 567ms (n = 497). However, during moderate weather, while outages occurred (2-26 minutes), the system recovered quickly. This internet service was used successfully with a variety of video-conferencing tools. These initial results demonstrated the Sky Muster™ Plus service was adequate for videoconferencing and therefore for videoconferencing for telehealth. These preliminary data were provided to Laynhapuy Homelands Health Service (LHS) in January 2020.

During the early stages of the COVID-19 Pandemic, LHS requested assistance to have seven Sky Muster™ Plus Services installed as a matter of urgency so telehealth could be implemented in their East Arnhem remote Aboriginal communities. At the time, the communities were closed and there were extensive restrictions on travel within the Northern Territory.

Through collaboration between NBN Co, SkyMesh (the Retail Service Provider), JMAC Comms (the contracted installer), the NT Senator's Office, the Chief Minister's Office and the researchers, 7 Sky Muster™ Plus satellite installations were done within approximately 3 weeks of the request. LHS were so impressed with the performance of these services they later requested an additional 4 installations for their communities via their retail service provider, SkyMesh. This paper will describe the process of evaluation and outline the preliminary results from testing the Sky Muster™ Plus service. These initial results indicate Sky Muster™ Plus is adequate for telehealth via video conferencing and could be potentially be used for smart diagnostic tools such as tele-monitoring devices.

Keywords. Telehealth, telemedicine, remote primary health, remote telecommunications, internet connectivity, collaboration.

1. Introduction

For approximately ten years, the National Broadband Network (NBN) has been establishing and improving Internet connectivity for Australia. In 2011, the NBN Interim Satellite Service was established with the first Sky Muster™ satellite launching in October, 2015 and becoming operational in April of the following year [1]. During the same time period, the Broadband for the Bush Alliance was advocating for better Internet services in rural, regional and remote (RRR) Australia. At the Alliance's Annual Forums representatives of the NBN listened and shared updates on the progress of the rollout of their network.

In 2018, **NBN™** Sky Muster™ satellite (not Sky Muster™ Plus) services were reported to be inadequate for telehealth [2] with research indicating issues with download limits, reliability and poor video-conferencing quality [3,4,5]. As part of their commitment to B4BA and improving their services to RRR Australia, members of NBN's management and satellite engineering teams visited remote health services and communities to develop a deeper understanding of the challenges and working environments of RRR residents, communities and

businesses. In 2019, NBN released the Sky Muster™ Plus service. This service was designed to allow individuals, small businesses, health services and small community groups to pay a higher rate compared to Sky Muster for a substantially customised service with several types of traffic being unmetered. This allowed videoconferencing-based activities with less concern for bandwidth/download limits and was potentially suitable for telehealth videoconferencing in clinics in small remote Aboriginal communities or cattle stations.

Videoconferencing-based Telehealth has been demonstrated to work over high quality "mining-grade" satellite internet (ie very expensive - approximately $40,000 per installation and $100,000 pa for connectivity for up to 7 sites) [6]. During the COVID-19 pandemic, quality health services were provided to people who were isolated by factors other than geography. With improved and cost effective NBN services and Medicare based remuneration for Telehealth consultations, a new business model for health delivery in remote Australia is now a reality. "Telehealth is a disruptive innovation that is changing health care, and its influence is likely to increase rapidly" [7]. The COVID-19 pandemic had demonstrated the value of telehealth to isolated patients and presents an opportunity to expand access to telehealth services for RRR people. It is important to note face to face consultation is the preferred mechanism for many situation but telehealth provides an viable option for a range of situations, particularly in a pandemic situation.

2. Methods

Sky Muster™ Plus services were installed on a rural property approximately 35kms South of Darwin in the 2019-2020 wet season (November – April). The first satellite service installation was successfully installed in mid-December 2019 and the second in late January, 2020. Both services were installed by the same technician (JMAC Comms). The first satellite dish was installed on a single story shed with large trees and palms surrounding the area. A second Sky Muster™ Plus service was installed later in the wet season on a two-story house which had a relatively clear line of site to the satellite. The services were provided as an in-kind contribution to the research by SkyMesh and supported by NBN Co.

Evaluation of the internet service was achieved using a combination of speed-testing tools, weather observations and qualitative user experience measures. The testing of internet quality was done using

Ookla speed test at random times and during weather events to determine how well the service would work during varying weather conditions. It was also deemed useful to determine how frequent and long outages would be in severe weather. The Ookla speed test uses servers located around the world to receive and transmit test data to Internet users. The test measures download speed, upload speed, duration of ping and gives the location of the test server used. A Netgear Nighthawk router was installed to provide internet connection via a Wi-Fi service to a local computer that was used for testing.

The weather in the "Top End" (geographical region encompassing the northernmost section of the NT) can be very severe in the wet season with cyclones such as Tracy (1974) and Marcus (2018). There are frequent storms with heavy cloud, torrential rain, strong winds and numerous lightning strikes. A weather index was developed quantifying the extent of cloud cover, strength of the wind, rain intensity and severity of lightning strikes. The weather index was an attempt to quantify the severity of the weather. Rain was rated from 0 (no rain) to 5 (torrential rain). Cloud cover and wind were similarly rated from 0 – 5 (see Table 1).

Table 1. Weather index description.

Score	Rain	Cloud Cover	Wind
0	Nil	Nil, sunny	Not noticeable or light breeze
1	Very light drizzle	Light/patchy, some sun	Breeze
2	Drizzle	Mixed light & moderate	Moderate
3	Light rain	Moderate	Strong
4	Moderate rain	Dark	Very strong
5	Heavy rain	Very heavy cloud	Cyclone strong

Testing was done between 16 December and 24 January. Further testing was done on the second satellite installation between 3/3/20 and 16/7/20.

2.1. Installations for the Laynhapuy Homelands Health Service (LHS).

In the early stages of the COVID-19 pandemic, the LHS sought confirmation of the performance of the Sky Muster™ service. Based on those preliminary data, LHS requested assistance to install seven Sky Muster™ Plus services urgently in their homelands to implement telehealth widely. Through collaboration between NBN Co and SkyMesh approval was obtained to use the same contractor who had installed the services at the research site. This reduced any possible variance in quality of installation. Additionally, the installer had not left Darwin through the pandemic and therefore was a minimal risk to the community and had extensive experience and knowledge of the East Arnhem communities. The contractor was able to obtain the required equipment.

At the time, there were extensive delays in obtaining the relevant permits through the Northern Land Council and the NT government. Assistance was sought from the NT Senator and the Chief Minister's Office to expedite the permit approvals. Through collaboration between the two offices (both sides of politics), the required permits were obtained within approximately two weeks.

There was a requirement to install routers to provide wireless access to the internet as well as to facilitate remote monitoring and management. Emerge (ICT company based in Katherine and project partner) pre-configured seven routers which were concurrently installed.   UPSs (Uninterrupted Power Supplies) were later connected to the systems therefore protecting against power surges.

3. Results
3.1. Download, upload and latency results from wet season testing.
The monitoring of download, upload and ping (latency) of successful connections are summarised in Fig 1. The mean download speed was 29.02 mbps, the mean upload speed was 8.82 mbps, and the mean ping was 567 ms (n= 497). Speed data during outage events associated with severe weather have been excluded from this data set' were excluded from this data set. There were frequent power failures during the wet season resulting in the Sky Muster™ Plus service failing. These events were excluded from the analysis. Deterioration of signal prior to failure were included in the data set.
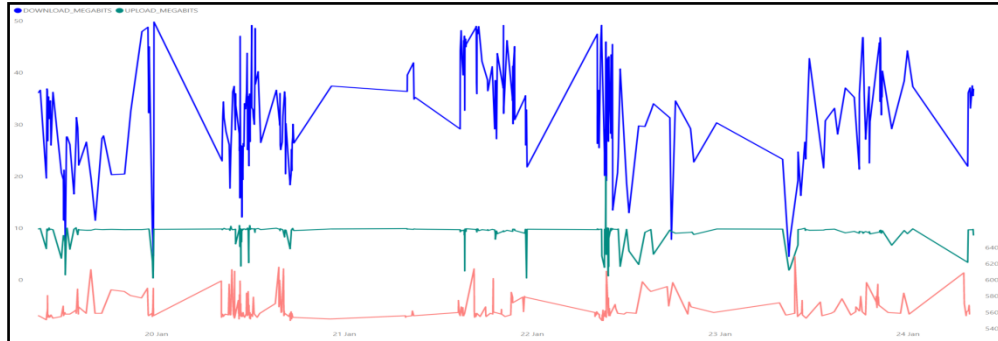
Figure 1. Speed tests 19 - 24 January 2020. Note the variability due to weather impacts on performance. Testing was specifically targeting adverse weather events and very little testing was done when the weather was clear. The aim of the research was to understand how adverse weather affected the performance of the service and determine how frequent and long outages would be due to adverse weather events.

3.2. Outages due to weather events.

Detailed weather observations and monitoring were done from 19th January – 24th February. The Bureau of Meteorology recorded 435mm of rain in the nearest observation station (approximately 8kms away from the satellite dishes) [8]. Outages varied in duration from 2 to 26 minutes. There seemed to be a trend for the download and upload speed to reduce prior to outage, with upload failing more often than download. There was a trend for outages to be longer when rain was light (score = 2) or moderate (score = 3). There were no events with torrential rain (score = 5) during the testing period. Moderate cloud cover (score = 3) with light drizzle (score = 1) seemed to have little impact on performance with download speeds varying between 28 and 45 mbps and upload speeds remaining fairly consistent around 9.8 mbps. Ping remained fairly consistent between 556 – 570 (derived from one daytime rainfall event). When heavy weather was approaching, downloads were often possible, but there were up-load errors. Upload error is defined as being unable to connect to the internet.
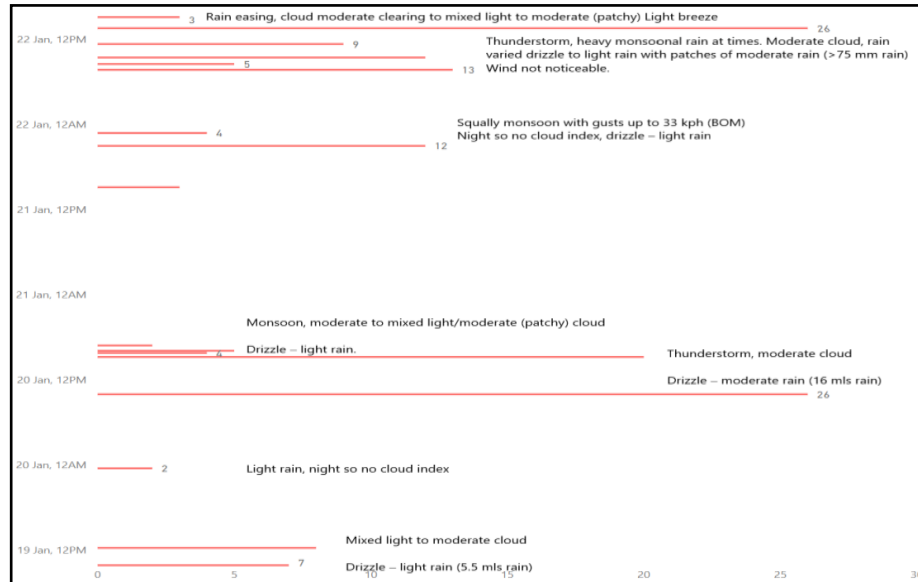
Figure 2. Outages 19 - 24 January 2020.Outages varied from 2 – 26 minutes. The testing period included monsoonal conditions with heavy rainfalls during this period. Weather events were targeted for monitoring in this research.

3.3. Download, upload and latency results from dry season testing.
Monitoring of the second satellite service was done at random times during the dry season (May – October). The mean download speed was 36.18 mbps, the mean upload speed was 8.97 mbps, and the mean ping was 566 ms (n = 28). There were few connection failures during this time.

4. Discussion

4.1. Dry season performance.
Monitoring of the second satellite service seemed to be reasonably consistent with a typical download speed of approximately 36 mbps, upload 9 and ping remaining consistently around 566. There were few connection failures during this period and these seemed to be related to scheduled outages for upgrade purposes. The sample size was small and other data were obtained by NBN with a small monitoring device, but those data were not available for this analysis. Up to three consecutive video- conferences on three different devices were successfully done although there was some freezing of images. There was some variability in performance which may be related to contention issues ie the amount of traffic on the NBN network or internal network traffic/issues. The Sky Muster™ Plus service seems to be a reliable form of internet suitable for

video conferencing (1-2 video conferences concurrently). However, for telehealth, it would be useful for the upload speed and bandwidth to be at least as good as the download speed to allow the remote clinician a sound source of video data on which to base decision making.

The reliability of the Sky Muster™ Plus service during the dry season is validated by the successful deployment of seven installations in remote Aboriginal communities. LHS indicated the services were working well with the exception of some router issues. When the clinician connected directly to the NTD (NBN's Network Termination Device) signal strength was adequate to do video-conferencing.   To alleviate this problem, SkyMesh provided an additional three pre-configured routers that could be used as "hot swappable" devices to replace non-performing routers until they could be restored. The performance of the service is further confirmed by the request from LHS to install a further four services in their communities several weeks after the first seven installations.

4.2. Wet season performance.
The Sky Muster™ Plus service, though affected by weather, performed well with good download and upload speeds the majority of time during the wet season. The Sky Muster™ Plus service, though affected by weather, performed above the assured download and upload speeds of 25Mbps download and 5Mbps upload the majority of time during the wet season. There were multiple outages during weather events varying from approximately 2 – 26 minutes. This preliminary analysis confirms that like all satellite systems, the service can be impacted by weather, but, further and more accurate testing needs to be done to gain a deeper understanding of how weather affects this satellite internet service. Although the weather index was subjective, it does provide an indication of weather activity and its impact on internet service performance. It may be the researcher's perspective on severity of weather events have been influenced by living in the NT for many years and a more rigorous method of monitoring weather events (eg via automatic weather stations) would be beneficial in understanding weather affects on satellite internet performance.

5. Implications for clinicians
Rain refracts the satellite signal therefore creating transmission errors. Data are transferred in 'chunks' and when errors occur, recovery is quick (ie within 1-2 minutes) because the protocol is designed to resend lost data.

When working in remote locations that rely on satellite telecommunications, light to moderate rain, will cause the satellite signal to fail, but the internet communication will recover quickly (ie within minutes). Preliminary trends observed indicate reduction of internet quality is a precursor to failure, and this continued for up to 9 mins prior to failure. However, when the system recovers, it recovers well with normal speeds. recovers to expected download and upload performance within X period of time. For day-to-day consultations these interruptions to connectivity can be managed as are other causes for delayed consultations. Clearly, there are other causes of poor internet service, such a router issues or contention due to large volumes of traffic on the service. The experience, including the speeds depends on the **network** technology and configuration over which services are delivered to a premise, whether the internet is used during the busy period, and other factors including equipment quality, software, broadband plan, signal reception, how the service provider designs its network, and latency (NBN Co, pers comm).

6. Conclusion

NBN Sky Muster™ Plus satellite internet is a significant improvement of previous NBN satellite products and in this test environment, results relating to bandwidth and availability suggest that it may be adequate for telehealth via video conferencing. It may be suitable for other telehealth activities such as transmitting data from smart digital tools. However, the traffic needs to be managed eg up to two connections may be viable on Sky Muster Plus, but in larger environments with greater traffic additional connections may be required. Given the bandwidth requirements for other smart digital tools, this service may also be suitable for other digital health applications including the transmission of data from telemonitoring devices. There needs to be further research to determine how weather affects satellite telecommunications and if there are mechanisms to strengthen the signal during moderate to severe weather. The team are investigating various options that may be available to prioritise health data transmission, particularly in an emergency. More accurate weather and transmission monitoring will be done in the 2020-21 wet season and options for minimising outages will be investigated.

During the COVID-19 pandemic, health services were provided to people who were isolated by factors other than geography. However, many of these services were delivered via telephone rather than video. With improved and cost effective NBN services and Medicare based

remuneration for Telehealth consultations, a new business model for health delivery for RRR is now possible. The research team will continue to work with project partners to develop innovative service delivery models for RRR Australia using affordable NBN internet services.

References

[1] Brown, T. NBN satellite launch: A historic moment for Australia. 2015 [cited 2020 06-08-2020]; Available from: https://www.nbnco.com.au/blog/the-nbn-project/nbn-satellite-launch-a-historic-moment-for-Australia.

[2] St_Clair, M. and D. Murtagh, A collaborative approach in remote Aboriginal communities – why has telehealth worked in the Laynhapuy Homelands? Rural Health Alliance Conference Proceedings, 2019.

[3] Robert Steele, A.L., Telehealth and ubiquitous computing for bandwidth-constrained rural and remote areas. Personal and Ubiquitous Computing, 2013. 17(3): p. 533-543.

[4] St_Clair, M. and D. Murtagh, Barriers to telehealth uptake in rural, regional, remote Australia: What can be done to expand telehealth access in remote areas? Studies in health technology and informatics, 2019. 266: p. 174-182.

[5] Nicol Turner Lee, J.K., and Jordan Roberts, Removing barriers to telehealth before and after COVID-19. 2020, Brookings Institute.

[6] St_Clair, M., et al., Telehealth-A Game Changer - Closing the Gap in Remote Indigenous Health in Three Remote Homeland Communities in the Laynhapuy Homelands, East Arnhem, Northern Australia. Studies in health technology and informatics, 2018. 252: p. 132-138.

[7] Meteorology, B.o. Noonamah, NT - January 2020 - Daily Weather Observations. 2020 [cited 2020 06-08-2020]; Available from: http://www.bom.gov.au/climate/dwo/202001/html/IDCJDW8061.202001.shtml

[8] Schwamm, L.H., Telehealth: Seven strategies to successfully implement disruptive technology and transform health care. Health Affairs, 2014. 33(2): p. 200-6.