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SUB-6GHZ 5G SLICING ON PUBLIC NETWORKS – FIELD RESULTS, OBSERVATIONS AND ROADMAP TO UBIQUITOUS 5G ACCESS FOR PROFESSIONAL MEDIA

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ABSTRACT

Spanning a period of over 24 months, telecommunications and broadcast services provider Telstra has conducted multiple trials alongside national broadcasters and sports producers, exploring the use cases, workflow, viability, and efficacy of advanced slicing techniques on the public sub-6GHz 5G network. These trials covered major events, live sports, and other similar contribution use cases and demonstrated the positive impact of slicing on feed stability and availability, particularly in areas of high network congestion. This paper examines the technical details of trials following the evolution from LTE QCI-driven prioritisation and scheduling, through the impact of Radio Resource Scheduling, and the realisation of slicing through the User Equipment Route Selection Policy.

INTRODUCTION

Ever since the “first generation” of public cellular networks, there has been a clear role and requirement for carriers to provide differentiated services, utilising scarce spectrum and infrastructure for as many varied use cases as possible. Emergency services, government communications and critical media have driven the need for ultra-reliable real-time communications over common radio infrastructure, leading to radio trunking platforms such as Project 25, Trans-European Digital System (TEDS), Digital Mobile Radio (DMR) and Terrestrial Trunked Radio (TETRA) (1). With packet switched 4th generation networks able to prioritise and schedule resource dynamically according to need, spectral efficiency not only increased dramatically but per-service Quality of Experience did at the same time.

The fifth generation of cellular networks (5G) has had significant interest from the professional media industry, as the promise of fast, ubiquitous, uninterruptable connectivity can revolutionise a broadcast workflow both technically and commercially. On this subject, IBC and Caretta Research recently released the *State of 5G for Broadcasters* study (2), which questioned the maturity and reliability of public network. The move to 3GPP Release 16 and 5G Standalone has taken significant time and expense for major carriers, and as the same report states: people in the content creation and distribution industry need solutions that are “turn on and go”, which requires a sustained level of communication and collaboration between broadcaster and carrier.

In this paper, what will be highlighted is the different methodologies used to optimise 5G New Radio (NR) cellular uplink, trialled in close cooperation between several national broadcasters, major carrier Telstra, and Telstra's global broadcast arm, Telstra Broadcast Services. In order to focus efforts and ensure initial technical and commercial validity, the trials focused on contribution quality uplink, either as a single low latency service (9 Mbps video, 10 Mbps payload), and optimally a mixed uplink service similar to tier-2 DVB-S (20 Mbps). These were chosen as they were analysed to be the most commercially viable in the short term – no doubt other use cases are valid and possible, and the opportunities and roadmap to a dynamic slicing future will be discussed as a conclusion.

5G MEDIA OPTIMISATION TRIALS – OVERVIEW

The below illustration highlights the areas on which Telstra has focused in its media optimisation trials over the last year.

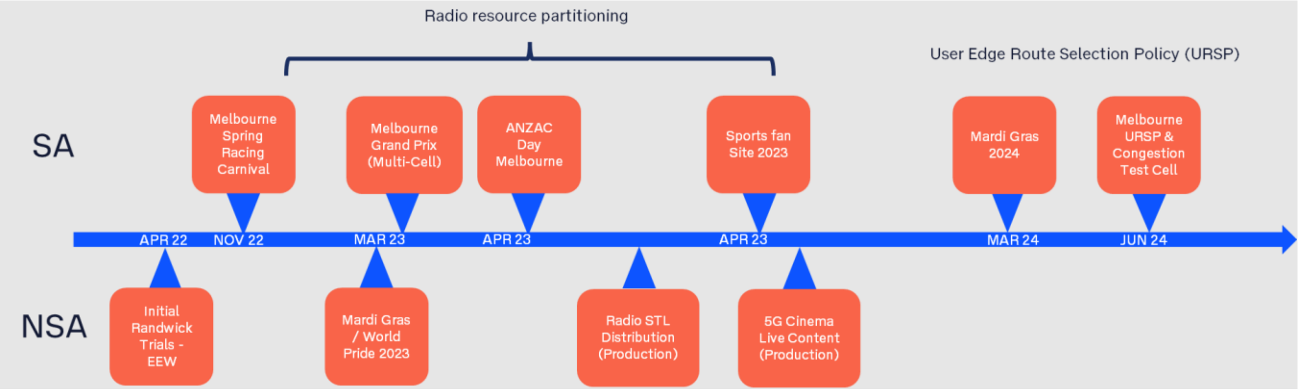

Figure 1- Timeline of Telstra Media Sliced and Optimised Cellular Projects

April-October 2022, Randwick Racecourse (Sydney, NSW, Australia)

The trials at Randwick represented one of the first opportunities to explore with a sports production company the impact of substituting a non-standards based cellular-bonding service with a service that would provide an assured service at a higher speed, with predictable performance and cost.

Figure 2 - Remote stewarding install position

Telstra Enterprise Wireless Engineering assisted with a service qualification, as RSRP (Reference Signal Received Power) and SINR (Signal-to-Interference-plus-Noise Ratio) are known to influence priority on the uplink radio scheduler (3), and for good measure the service was also assigned a non-default LTE QCI, mapped 1-1 to a NR 5QI. The QCI / 5QI combination was already implemented in market as an "Accelerator", not providing guaranteed service but priority on the Relative Priority Scheduler (RPS), a standard algorithm used in LTE, 5G Non-Standalone (NSA) and 5G Standalone (SA) systems.

Initial performance exceeded the service qualification – the graph in Figure 3 indicates the observations over two days, when cell loading (indicated by yellow line) varied, and the orange line, indicating uplink throughput, stayed extremely solid at over 100 Mbps.

Over the next 18 months, regular trials were conducted for multiple use cases from remote stewarding to remote production – a key point of note was the stability of the signal and the reliability of achieving over 550 Mbps downlink and 100 Mbps, later 130 Mbps uplink (due to implementation of E-UTRAN New Radio Dual Connectivity, or EN-DC in the network), all from a single modem and service.

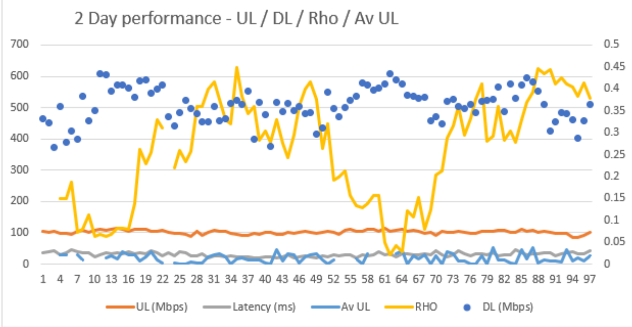

Figure 3 - U/L (orange) throughput and latency with respect to cell load (yellow) over 48 hours

Latency was also found to be encouragingly small – averaging 18 ms RTT at the application level.

November 2022, Spring Racing Carnival (Melbourne, VIC, Australia)

This event represented the first attempt made at standalone 5G slicing, to be performed at Flemington Racecourse with direct assistance and involvement by national commercial broadcaster Network 10.

In this scenario, the goal was to support both 10 Mbps as well as 20 Mbps uplink scenario, corresponding to a single camera uplink or a multiplex service with similar parameters to a satellite service (DSNG).

The radio network would need to define the logical partition, and confirm that prerequisites such as standalone mode be in place. The Cradlepoint W2005-5GB was used as a known entity capable of 5G Standalone mode for trial purposes. The trial equipment used LiveU or Telstra Broadcast Service’s own Internet Delivery Edge, which can use SRT to provide network and stream level statistics.

In particular, the Melbourne Cup race was an event to track for impact, due to expected large number of people on or around the track causing impact.

Out of an abundance of caution, when high traffic was seen on the network shortly after the race, the transmitting unit was switched out of the slice and capacity restored to the cell. Doing so, as can be seen in Figure 4, resulted in a measurable increase in delay and jitter of the received packets. As a first trial, the results are encouraging as they proved that defining and provisioning a video uplink was not only possible but effective in improving uplink quality and stability.

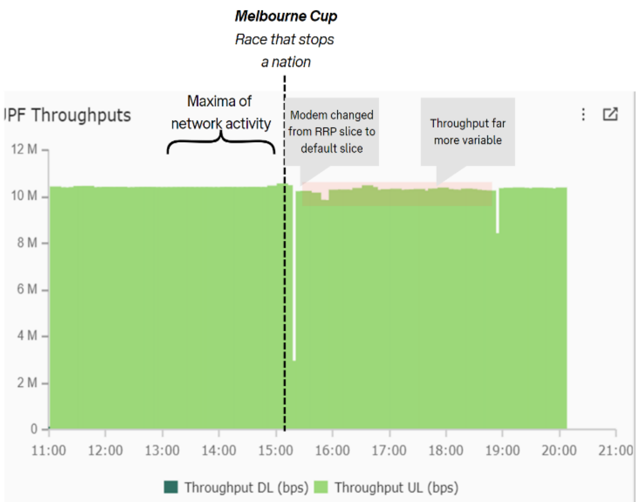

Figure 4 Throughput performance - 10 mbps slice - major race day

March 2023, Mardi Gras and World Pride (Sydney, NSW, Australia)

The Sydney Gay and Lesbian Mardi Gras was a key trial, and as it modelled another opportunity to explore a 5G radio resource partitioning slice, due to limited analysis trial it was decided to not risk network stability on what was expected to be a high profile event with extreme network congestion.

This trial was requested by national broadcaster Australian Broadcasting Corporation (ABC), which was host broadcaster for this event. The key challenge was that the normally heavily attended event coincided with World Pride, boosting numbers to what was later reported to be 310,000 contained in an area of approximately 1 square kilometre.

Figure 5 - Installation position and bearing to serving cell

Based on the success of the Randwick trials and the running theory that power, signal quality and QCI based prioritisation was effective, a similar service qualification was undertaken, and position found, as shown in attached diagram. The modem and antenna were remote to the OB truck and powered via PoE using 80m of Cat-6 cable.

In anticipation of issues related not to traffic priority but access priority, a novel implementation of access was proposed where the LTE-based Physical Uplink Control Channel (PUCCH) would receive a QCI marker that enabled priority access and a 1 mbps first fill algorithm on the Rate Control Scheduler (RCS). The Physical Uplink Shared Channel (PUSCH) would host the majority of the data on NR band n78, and whilst not specifically prioritised at the network level, quality would be enhanced by the high SINR and RSRP afforded by the install, location and equipment environment. The key reasoning behind this was that if the PUCCH would remain stable amongst high congestion, the overall data throughput would be respond appropriately to requests from the scheduler and not be demoted. (3)

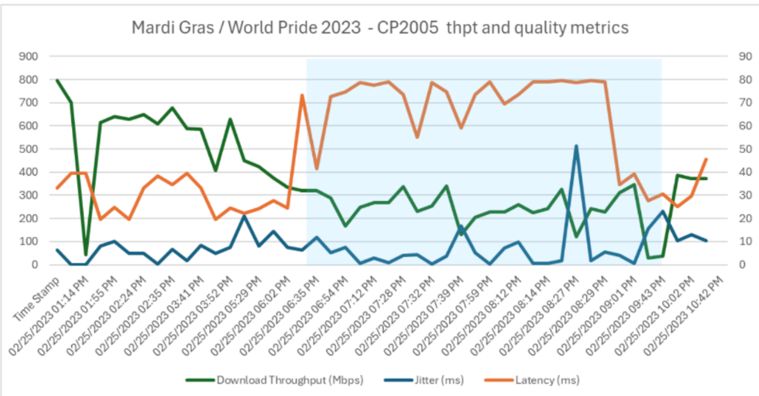

Figure 6 Uplink, Downlink and Latency Measure during event – peak period highlighted in blue. Significant but not service affecting degradation occurred at periods of peak activity.

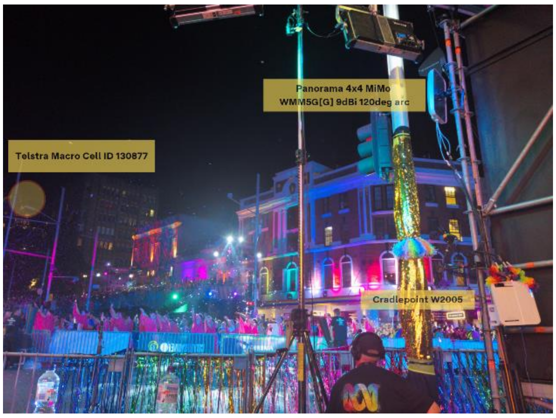

Figure 7 - 4x4 antenna mounted 3m beside stage, aligned within 3 degrees to tower. Modem is mounted bottom right and dressed in a garland.

In terms of results, expectations going in were to assume a “better than nothing” outcome, with hopes for approximately 10 Mbps sustained uplink. Whilst uncongested the link performed at 820mbps in downlink and 108Mbps in uplink, but the degradation of the link was nowhere near expected at peak congestion. The enhanced modem had no less than 176 Mbps in downlink and no less than 36 Mbps in the uplink, despite most handsets and bonding units in the vicinity being either unable to connect or achieving less than 0.5 Mbps in either direction. The end user, ABC, found no issues with the link and used it for much of the night, however when live content was not flowing, a separate 20 Mbps UHD HEVC stream was uplinked via SRT to the Telstra Broadcast Ops centre in Sydney, with no observed breakup or dropped packets. As a result, the trial was considered a strong success due the ability to sustain the uplink throughput and quality when alternative bonded solutions had failed to do so.

March 2023, Global Motorsports Event (Melbourne, VIC, Australia)

Following from the successful first RRP trial at Flemington 5 months earlier, Network 10 invited Telstra to do a wider trial, one based on not one camera and area but multiple uplinks across a large precinct. The event requested was globally known and held in Melbourne every year, and provided a new high congestion opportunity to trial slicing effectiveness.

This event represented a large investment in manpower and network, as slicing was enabled in not a single cell but in multiple cells in the area, applying the same NSSAI (Network Slice Selection Assistance Information) and uplink prioritisation level to multiple towers in the area. Although a fixed, qualified position was in place, this trial also implemented a portable user edge, incorporating power, encoder, SA modem (Cradlepoint R1900-5GB) and 4x4 MIMO antenna into a single suitcase.

Figure 10 - Multi-cell slicing enablement

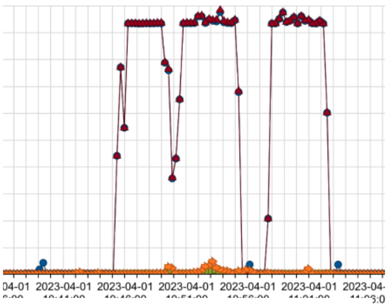

Figure 9 - Received stream bitrate, degraded RF

Figure 8- Portable "Parsec" slicing enabled encoder and modem, at OB position for weather cross

The learnings from this trial were vast and would undoubtedly take more pages than this paper allows, but the assessment of the mobile unit, in different RF scenarios, indicated that there was some complexity in scenarios where RF was poor, and power negotiation, typically more available in RRP scenarios, was hard to control particularly in handover between cells. Whilst the tower can alter power levels dynamically for downlink, in uplink the UE transmit power is constrained partially by regulation and partially by timing control (3), and achieving the slice guarantees appeared more complex. Still, by adjusting the alignment of the portable unit (i.e. turning it) for greater SINR, adding more argument to the hypothesis that guarantee of bandwidth must have consideration of RF strength and SINR.

August 2023 – Live to Air, Major Public Area for Global Sporting Event

The next trial was instigated by a request from national commercial broadcaster Nine Entertainment Corp, with a request for assistant in a series of live crosses at a major global event that attracted tens of thousands of people at dedicated fan zones, that typically severely hindered even bonded cellular solutions.

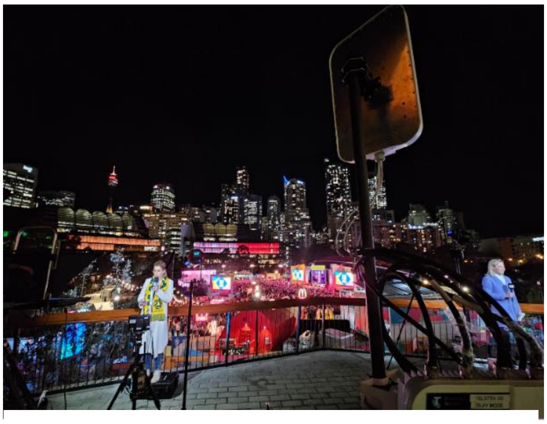

Figure 11 Live to air, heavy congestion event.

The decision was made to use this as an opportunity to trial the Telstra Enterprise Wireless's new automations for fast service qualification (SQ), SIM activation and slice commissioning, validation, and observation. Once SQ verified suitable RF conditions, a test slice was set up at the Telstra Broadcast Pitt St facility and verified remotely, with throughputs in excess of 90 Mbps uplink using the same Cradlepoint W2005-5GB modem as used in other Sydney trials, but with a new 5G Standalone mode firmware for trial support purpose.

The modem and antenna were mounted to a 3 metre PA stand and weighted down, which had been found to be a surprisingly suitable and cost-effective method of providing sufficient height to achieve the SQ requirements. Engineering teams were able to confirm in advance of the event that the modem was connected, slice operational, little to no impact on other / general slices.

Operationally, Nine encoded the HD 1080i50 video in an existing Dejero unit, interfacing the Cradlepoint via ethernet and auto-prioritising based on quality and availability.

Whilst many measures were taken, it was clear that the partition was working efficiently despite the crowds – 95% of on-air traffic was routed via the unit, in a solid proof point that it was possible to achieve (relatively) fast qualification, configuration, operation and validation of a new slice in a new area in a short period of time (less than 24 hours).

March 2024 – Mardi Gras Revisited, 5G Standalone on shared slice – single S-NSSAI

Based on the success of the year before, another opportunity arose to validate slicing at one of the most network congested events in Australia– however this year the Telstra Enterprise team opted to trial a new modem and the first of the policy-based architecture that had been in planning. Instead of the network partitioning the resource, the edge would request the S-NSSAI of the cell, which matches the request with a profile preconfigured for video uplink first-fill prioritisation (10Mbps).

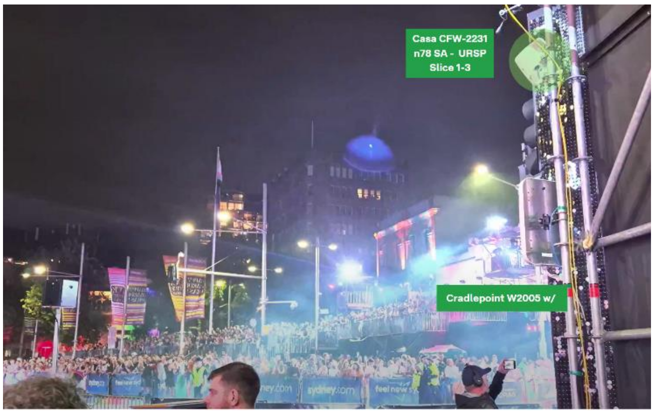

Figure 12 - Dual modems, sliced and unsliced

ABC were to use this for a similar use case, but also as a backup for primary program delivered via DSNG.

To aid as a comparison, a Cradlepoint W2005-5GB with 4x4 MIMO Antenna (same unit as used previously, but without any prioritisation either on LTE or NR. The hypothesis was simple – a successful trial would see uninterrupted uplink on the unit attached to the prioritised slice,

There were no issues seen during the evening, and the lack of dropped packets and consistent 30 ms RTT from ABC's edge to HQ and back indicated the stability of the policy slice to be as good as the radio resource partitioned one.

The notable observation was the reference unit – the same Cradlepoint in the same position as the previous year – performed significantly worse despite strong SINR and RSRP measurements. Not only was overall throughput worse, also jitter increased and the minimum sustainable stream reduced, regardless of band or approach.

It is possible that year to year there may have been a sizeable increase in the public 5G handset fleet to impact contention and performance. However, it is also likely that the PUCCH on LTE experienced congestion as expected, and without priority or rate shaping on the control plane as configured last year, the data plane could not maintain the stability of throughput, despite the stronger power and SINR on the PUSCH (n78).

June 2024 – Proof of Value trial, URSP based

With 5G slicing and policy-based slicing now proved beyond concept for professional video, investigations are now switching to proof of value experiments. The following diagram represents the video chain set up for experiments currently underway.

The goal of these trials is to prove end to end industry chains, without alteration except for the point of difference (in this case, a prioritised 5G slice as opposed to a default slice). The chain below represents in-market products and systems, as a single uplink video chain sent to two separate SRT headend. The proof of value being measured is the effect on the output video once 5G QCI parameters are enforced, by gradually increasing traffic in the cell to the point that the scheduler actively prioritises the marked traffic. The effect is represented visually by two screens – one with sliced traffic and one without – and results so far have indicated that the traffic not carried by the slice initially increases latency (via SRT retransmit) compared to the sliced traffic, to the point that the SRT latency limit is reached at which point the video breaks up, whilst the sliced traffic maintains stability and latency.

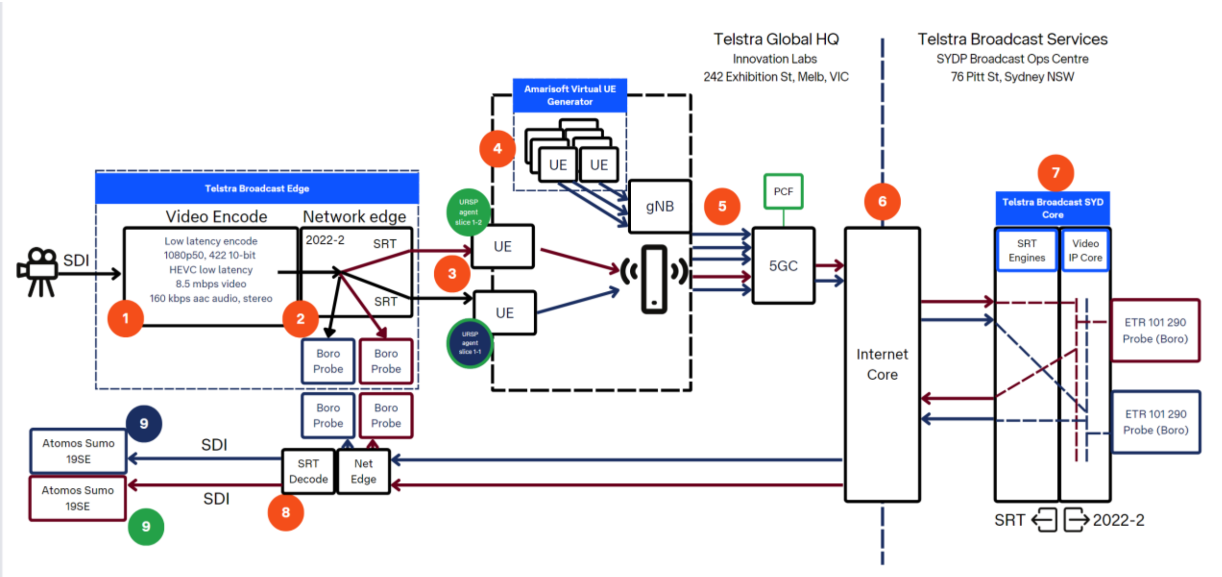

Figure 13 – Artificial congestion trials on public network, Telstra Labs

COMPARISON OF TRIAL PATTERNS AND OUTCOMES

5G NSA with RF optimisation, LTE prioritisation

The Randwick extended trials and the Mardi Gras 2023 and 2024 comparison validated a key assumption for broadcasters – that uplink priority, throughput and stability is significantly influenced by the PUCCH / PUSCH ratio, (4), which can be achieved by carefully considering deployment position, equipment and alignment. MIMO beamforming also has a positive influence, particularly in urban environments, and consideration should be given to antenna positioning and distance from other transmitters. QCI and 5QI factors (interrelated in NSA mode) are also important for both access and throughput – and if available certainly assist in high congestion environments. It was noted in other published trials that there was an assumption that NSA would be ineffective, as uplink was carried over LTE (5), but in most networks this is not the case as LTE is only used for PUCCH, with PUSCH carried over NR (4). And as discovered, if the PUCCH is disrupted as seen in Mardi Gras 2024 trial, the stream throughput will likely be erratic.

Whilst not strictly slicing, it is worth noting that this pattern is available today on many NSA enabled carriers, provided commercial and technical mechanisms exist for non-emergency LTE or NR prioritisation.

Regarding Radio Resource Partitioning

With the ability to offer precise control over resource allocation and scheduling policies at the radio level, RRP has been considered attractive for broadcast use cases, particularly as it can provide the guaranteed QoS, isolated from other traffic. In our trials, it was noticed that the RRP use cases worked at events where bonding may have been unreliable, with reliability and throughput matching DSNG and DENG (point-to-point microwave) scenarios – and for much the same reason (dedication of resources).

The core challenge with RRP comes with the network-taxing nature of its deployment – all towers in the target area must be enabled with the slice, requiring standalone mode to deployed at each and capacity reserved, whether used or not. Whilst this will eventually happen, in the uplink direction there are particular challenges when it comes to handling poor RF conditions for the UE, and degraded overall performance when there are multiple uplink units.

The approach of RRP may well prove to be an option for large major events, particularly those in defined precincts such as the motorsports use case previously mentioned, however it should be noted that this approach does require appropriate controls for management and monitoring to validate the uplink stability of multiple mobile units, particularly ensuring coordination between sending units to protect others on the slice.

A DYNAMIC 5G MEDIA ECOSYSTEM THROUGH URSP

User Equipment Route Selection Policy (URSP) could be considered a “late entrant” to the 5G standalone slicing deployment; however, it has been well defined in standards since 2020. (6).

Key to any deployment is simplicity of enablement, and a key consideration is that from the User Edge, all that is required is a software module that enables application routing and to receive the appropriate S-NSSAI from the network. This has already been implemented by several enterprise modem manufacturers, and handset manufacturers have already explored its use. It should be noted that there exists in the US potential concerns regarding the use of “application-based acceleration” in relation to federal Net Neutrality legislation, however this does not prevent handset OS manufacturers from implementation in regions where this is not in question. (7).

Network operators claim that URSP gives more flexibility than alternative methods when fine tuning of slice parameters, ensuring that the slices are only enabled *when required*, improving overall network utilisation efficiency and performance. (6)

There are also increased benefits for broadcasters of a more dynamic, as-needed ubiquitous slicing interface. Consider a field journalist being able go to air with breaking news, using only a mobile handset that routes the critical video traffic via a slice only when going to air, or broadcasters being able to select different tiers of acceleration and reliability based on use case and application. Or a remote director, able to control via proxy content critical to the shoot, whilst the main essence is uploaded asynchronously via a lower cost tier.

As it is becoming apparent that more and more large 5G SA-enabling carriers are progressing down the URSP route, the timing becomes even more important for broadcasters to collaborate, to ensure that workflow, charging models, supported equipment and expected service levels are accommodated.

The role of public networks with private 5G and non-public networks (NPN)
It should be noted that the frameworks and concepts of URSP are not incongruous and in fact can accelerate the wide range of use cases that NPN can provide for media. For example, if spectrum is available and able to supported by existing infrastructure, it can be configured as it's own NPN slice, completely with its own network function, security mechanisms and QoS policies. (6) The User Equipment Route Selection Policy would request access to the NPN, which the NPN controller would authorise under its own policies, and the session transferred to the private spectrum.

This has the potential to assist with UE consolidation, and increased commercial and technical flexibility as options to use public or private spectrum could be made on a more dynamic basis, with regards to availability, coverage and capacity, and of course, cost.

CONCLUSIONS

With many carriers beginning the transition to 5G standalone architecture and increasing demand on uplink from broadcasters utilising cellular contribution, Telstra leveraged the unique opportunity to collaborate directly with broadcasters and its own wholly-owned broadcast subsidiary Telstra Broadcast Services, and explore the effect on video uplink quality using multiple slicing and prioritisation techniques.

The trials presented by Telstra in this paper have demonstrated that live uplink over 5G network slicing is not only feasible but has a positive effect on stream availability and stability, which when combined with appropriate commercial models and workflows will undoubtedly benefit broadcasters and carriers alike. Key findings, for example the impact of radio quality on achieving guaranteed bitrate and the importance of stable control channels, should become a discussion point for future collaboration between broadcasters, carriers and standards bodies. While challenges remain, it is important that collaboration be sustained such that future dynamic 5G media ecosystems become globalised and commoditised.

It is likely that URSP will become the dominant form of slicing encountered by broadcasters in the upcoming years, and its flexibility, efficiency and increased potential for standardisation make it suitable for broadcasters to engage carriers and service partners to understand and agree the roadmap, not just for technical capabilities but also to agree charging rates, deployment workflows and service level agreements. By embracing this technology and working together, all parties can unlock new possibilities for content creation, distribution and consumption in the “real” 5G era.

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