5G TRIALS AND TRIBULATIONS

E. S. King[1], A. Buchan[2], D. Owens[3]

1: Anri Consulting for DCMS, UK, 2: DTG, UK, 3: VMO2, UK

ABSTRACT

DCMS 5G Testbeds and Trials-funded VISTA investigated in-stadium coverage for sports where an 'action replay' from multiple angles adds to the watching experience.

VISTA considered the use of the Further enhanced Multimedia Broadcast Multicast Service (FeMBMS) with on-site 5G New Radio (5GNR), Multi-access Edge Computing (5G-MEC) and containerised media encoders.

VISTA has developed a Mobile Network Operator (MNO) - approved, mobile-friendly live media broadcast chain for stadia.

This paper, 5G Trials and Tribulations, sets out what VISTA aimed to achieve, how it achieved those aims and some of the problems along the way.

INTRODUCTION

Big stadium events are attended by large numbers of people and the technology choice to distribute content is limited. Wi-Fi doesn’t scale and can’t cope with the user density. Cellular technologies can fix these issues but are costly and have a long return on investment (ROI), especially in a stadium which is only used for a relatively small proportion of the time.

Stadia offer an ideal environment to test FeMBMS and provide one of those, increasingly infrequent, opportunities where the viewers are watching the same thing ‘live’ simultaneously, albeit with a degree of personalisation.

The VISTA team ‘players’ changed. Covid hindered progress and media rights were tricky. It was a rollercoaster ride, but in the end the 5G VISTA team found a way of making FeMBMS work for all involved and provided eco-friendly, experience-enhancing content into stadia.

THE PROBLEM

VISTA primarily addresses the frequently-cited issue of a lack of bandwidth at live events to distribute audio-visual (AV) content to large audiences.

Large, live events provide a real challenge for MNOs, with demand for data peaking at key moments. At these times, it's difficult to access the network, let alone premium content. Overcoming this issue by increasing unicast delivery bandwidth doesn't stack up financially for MNOs.

By using FeMBMS, rather than unicast, VISTA delivers multimedia content efficiently and cost-effectively whilst maintaining quality of service (QoS) regardless of the number of users.

BACKGROUND

Local broadcasting for sporting events isn't new, but not even the most ardent fan takes a transistor radio to a stadium nowadays. VISTA put content on fans' phones, '*getting them closer to the action*' cost-effectively.

The prefix '*Further evolved*' (the Fe in FeMBMS) gives away the fact that the Multimedia Multicast Broadcast Service (MBMS) isn't a new idea, it's been around since the 3rd Generation Partnership Project 3GPP Release 5 (3GPP Rel. 5) of 2001.

The problem with FeMBMS is that not everybody is convinced it's a good idea.

- Broadcasters like it (because it's incredibly like the tried and tested methods they've used for years). If everybody watches or listens to the same things at the same time; it's incredibly efficient and cost-effective.
- Communications Service Providers (CSPs) aren't so keen. Fixed and mobile connectivity has advanced to the extent that Over the Top (OTT) services allow most people to watch what they want when they want.
- Equipment manufacturers are divided. The chipsets supporting FeMBMS have been produced, but handset manufacturers aren't exactly rushing to put them into their latest devices.

MBMS was introduced, with the aim of enabling multicast or broadcast AV content over 3G Universal Mobile Telecommunications Service (UMTS) Radio Access Networks (RANs). However, the UMTS RAN restricted bandwidth meaning the user experience was limited to audio or poor-quality video.

MBMS hasn't been without success. Reliance Jio claim 100 million users with eMBMS devices and 225,000 eMBMS-provisioned eNodeBs (4G base stations) in its network.

The aims of VISTA were to demonstrate the technical capabilities of FeMBMS (in receive only mode/ROM) and to promote its business potential (which is key to driving handset and ecosystem development).

NOVEL IDEAS

By providing live, multi-angle high definition (HD) AV streams and interactive content direct to handsets in stadiums and across the UK, the 5G VISTA project aims to deliver new experiences for live events. Showcasing new in-stadia digital experiences, VISTA aims to enhance customer experience and to increase channels of engagement.

This has many applications (stadium sports such as football or rugby, more distributed sporting events such as golf or motor racing, concerts and music festivals). Additional features can be deployed such as AV content, accessibility information, advertising and sales opportunities, event information, statistics and analysis.

The appeal of FeMBMS is that it costs the MNO roughly a tenth of an equivalent unicast distribution deployment.

In addition to the distribution network, VISTA developed a low-cost broadcast contribution system using containerised media encoders in 5G-MEC.

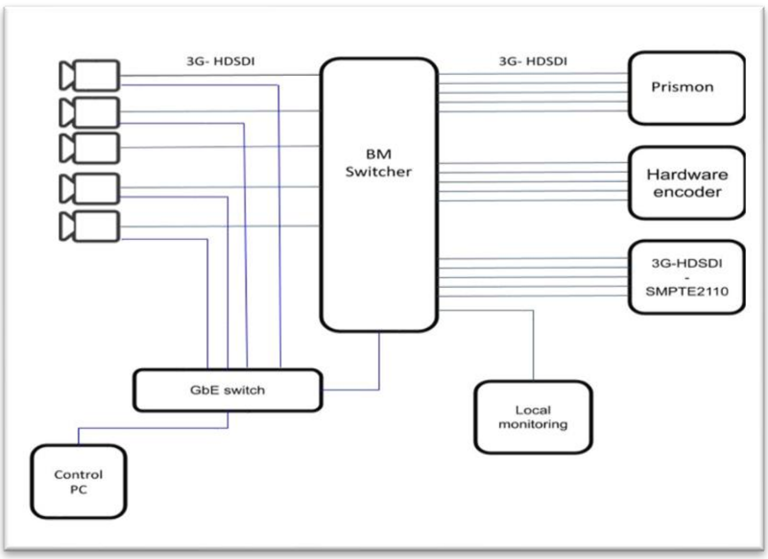

FIGURE 1 - VISTA BROADCAST CONTRIBUTION SYSTEM

VISTA combined traditional broadcast contribution technology such as Serial Digital Interface (SDI)-connected cameras, Blackmagic ATEM video switchers with 5G-MEC-based encoders to deliver content processing.

Instead of having dedicated video encoding hardware needed at all venues where the distribution solution is deployed, a version of the technology can be deployed as an application on commercial off the shelf (COTS) hardware or cloud services which is brought into service only when needed.

MATHEMATICAL THEORY

If a 1 Mbps unicast AV stream supports a single user, 1 Gbps is required to support 1000 such users.

With FeMBMS a single 1 Mbps stream would support all 1000 users.

VISTA's aim was to deliver six HD (720p, 60fps) feeds to user devices. VISTA's broadcast contribution system delivered these feeds as constant bitrate (CBR) high efficiency video coding (HEVC) streams. Each stream's bitrate was around 3.2 Mbps.

As an MNO, VMO2 had access to 10 MHz in the 700 MHz licenced space (centre 782 MHz). With 64 QAM modulation, this was (just) enough to support six 3.2 Mbps feeds (19.2 Mbps) over a single-input, single-output (SISO) antenna

To put these rates into context (with comparable broadcast technology) the UK DTT HD multiplex (PSB3) carries 10 services and uses 256 QAM at a data rate of 40 Mbps in 8 MHz bandwidth giving 5bps/Hz.

ECONOMIC ARGUMENTS

Massive MIMO (mMIMO) and beamforming can be used to make the most of available spectrum. With 100MHz channels, using 256 QAM, with the ability aggregate 5 channels together a single gNodeB (5G base station) would is able to deliver 5 Gbps.

A private network for a modestly sized stadium (of 20-30k capacity) might consist of 2 gNodeBs (around £400k) a large stadium (of 80k capacity) with 12 gNodeBs might cost around £2.5 million or more.

It's difficult for a MNO to make this sort of investment in an environment that isn't used that often, how are they going to make their money back?

A FeMBMS stadium deployment costs around £300k based on the VISTA deployment model.

VMO2's experience suggests capital costs represents about a third of total costs (the remaining two thirds being support and maintenance over ten years).

Using this cost model, the total cost of the modestly sized stadium over ten years would be around £1M. The large stadium's ten-year cost would be around £6M.

Verizon's multi-angle viewing service for the Superbowl a practical example of the cost of unicast. To prepare the stadium and surrounding area Verizon installed 281 base stations, 70 miles of fibre, and upgraded distributed antenna systems (DAS), with a total overall cost of over $80M.[1]

VISTA's research suggests deploying FeMBMS services at stadia is commercially viable even for clubs with attendances of around 20k fans[2].

EFFICIENCY AND COST REDUCTION

The infrastructure needed to deploy a unicast network capable of supporting live AV in busy areas costs round ten times that needed for a broadcast network.

There are also significant energy savings.

A FeMBMS base station uses around 125W. Two base stations (250W) can be used to cover a 20-30k capacity stadium.

A traditional unicast base transceiver station (BTS) uses around 10kW. The same stadium would require 2 BTS (20kW), 19.75kW more.

DESIGN APPROACH AND EVOLUTION

VISTA development was carried out over three phases.

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[1] https://www.verizon.com/about/news/verizon-and-nfl-5g-future-football
[2] 5G VISTA Sustainability Report https://www.digicatapult.org.uk/news-and-insights/publications/post/5g-vista-sustainability-report/

PHASE 1

Phase 1 (depicted in Figure 2) was a technical demonstration of the FeMBMS platform at Digital Catapult in London. This phase used pre-stored content rather than an OTT content provider.

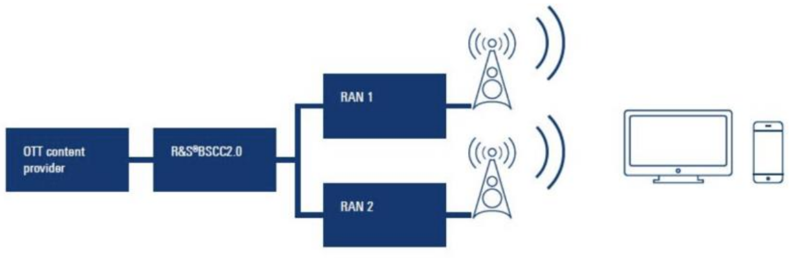

FIGURE 2 - PHASE 1 ARCHITECTURE

A Software Defined Radio (SDR) receiver (receiving RTP) was used instead of Samsung devices for receiving and demodulating the FeMBMS signal, the output was then distributed via Wi-Fi to the handhelds (as no handsets with FeMBMS capability could be obtained). A basic demo app showed the video on handsets.

PHASE 2:

Phase 2 (shown in Figure 3) integrates live content into the demonstration. This includes live cameras, production and master control, MEC and necessary processing before transmission over FeMBMS. No FEC was used. An app, more closely reflecting the final user experience was tested. This also allowed the option to edit and insert graphics, stats and additional content.

The production and master control were included to provide monitoring, distribution, playout and conversion of the camera feeds and other inputs.

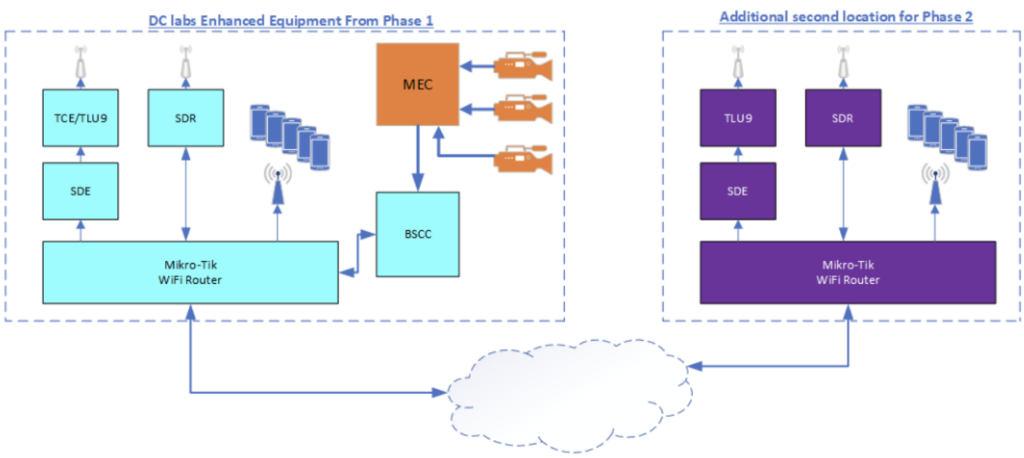

FIGURE 3 - GLASS TO GLASS ARCHITECTURE

PHASE 3:

Phase 3 (shown in Figure 4) demonstrated the full end-to-end solution during a live event. This included the content generation as tested in phase 2 and an extended FeMBMS platform installed on site, covering the venue.

Tests were planned with FeMBMS-capable handsets on which the VISTA app was installed. Content was simultaneously broadcast to other locations, as well covered by FeMBMS services.

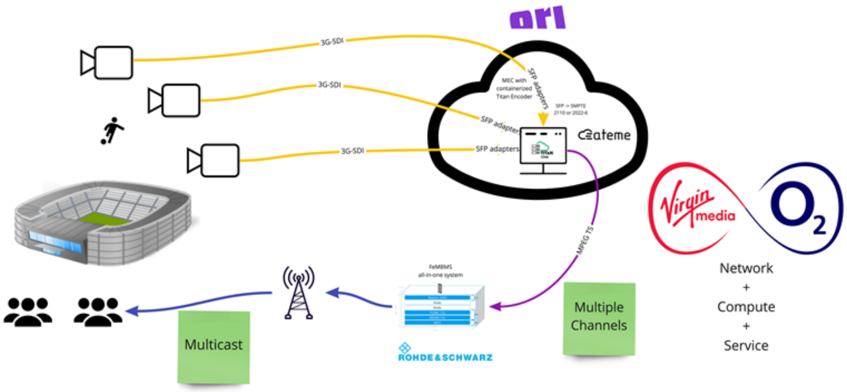

FIGURE 4 - TRIAL ARCHITECTURE

Initially, 5MHz was chosen, which supported 3 x 720p, 60 fps mpg4 streams at around 3.4 Mbps (10.2 of 11 MHz). This was a robust setup and did not require Global Navigation Satellite System (GNSS) timing.

The introduction of 10 MHz bandwidth and 6 streams tested SDR processing and input/output capabilities.

We needed to reduce the encoding level to around 3.2Mbps (19.2 of the available 20 Mbps) to ensure 6 streams could modulated on to 64 QAM 10 MHz carrier.

The move to 10 MHz also required precise timing. GNSS was required for both the FeMBMS transmit and receive to minimize clock drift (Figure 5 shows blurred constellation diagrams caused by clock drift).

TRIALS

The project carried out technical measurements of the end-to-end solution in both a lab environment and in a live environment.

LAB TESTING

Lab testing was carried out at Digital Catapult’s 5G Future Networks Lab in London and the aim of this was to verify the end-to-end FeMBMS solution ‘glass to glass’ before live deployment.

A live camera was set up in the lab to capture images from outside. This was fed through the network (as described in Phase 2), to an FeMBMS SDR and then onto Samsung handsets via Wi-Fi.

The original system suffered from delays of up to two minutes glass to glass. The delay was caused by timing issues. The use of common time sources significantly reduced end to end delay.

Further work, including a hardware system that could support 6 Ateme containerised encoders, meant we were finally able to reduce the glass-to-glass delay to 2 seconds.

Our application trials showed that customers liked delay to be closer to 7 to 10 seconds. As this allowed them to process what they had seen live in person and find the best camera angle to watch it again on the broadcast system.

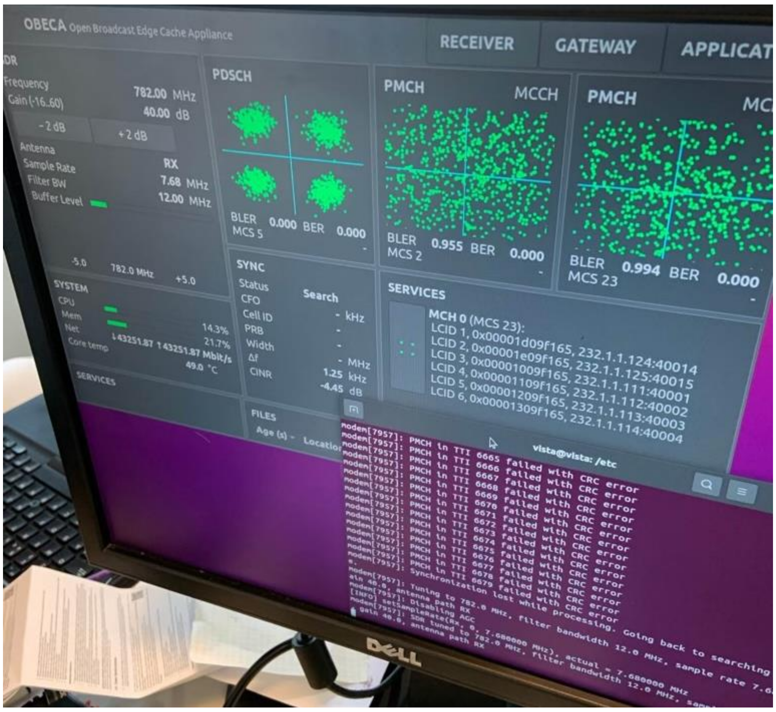

FIGURE 5 - TIMING ISSUES

LIVE TESTING

Technical measurements (broadcast and unicast) were then carried out at the O2 Arena during a live show. Unicast measurements were taken from the 4G network at the O2 Arena. The aim was to prove the stability of the broadcast network regardless of the number of (unicast) users in the arena.

A temporary FeMBMS was set up at Suite 209 in The O2. The signal was transmitted with these parameters:

- Centre Frequency: 782MHz
- Bandwidth: 10MHz
- Sub Carrier Spacing (SCS) 1.25KHz
- 2 x HD streams
- The initial transmit power was -40dBm, this was changed to 0dBm (1mW) later in the test

Readings were measured with the Kathrein surveying software using a TSMW as a receiving scanner. The survey took place before and during a show at the O2. This was to see if existing uplink noise would affect the readings or performance. Customer Experience for data was measured at the same time (LTE preferred) using bit rate measurement equipment on handsets which were streaming 6 videos.

The initial signal was not of sufficient power to provide a decodable FeMBMS signal. After the power change the scanner showed a good signal of sufficient quality to broadcast a multi-stream broadcast (in this case 2 streams).The Carrier to Interference and Noise Ratio (CINR) remained high during the show for the FeMBMS signal. LTE data rate fluctuated during the show.

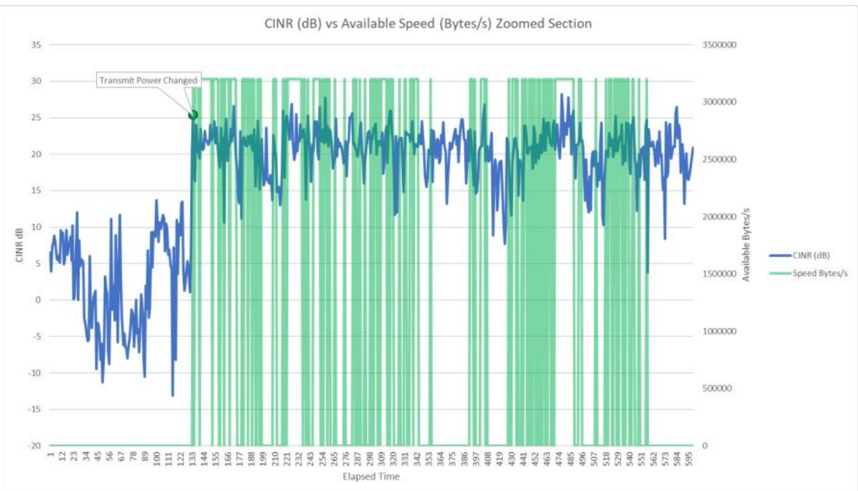

FIGURE 6 - POWER AND CINR

Figure 6 shows decoded FeMBMS received signal power (RSRP) and CINR before and during the show. As can be seen, the customer generated noise had no noticeable effect. The transmit power change can be seen clearly.

Figure 6 also shows that when the transmit power was increased the Bit Error Rate (BER) fell and stayed low. This is relevant as BER will have to be low to support a good quality of service.

FeMBMS was able to support 64 QAM modulation throughout the show. The higher the order of modulation the higher data throughput can be supported on the cell and 64 QAM a modulation rate that can easily support the 25 Mbps to distribute the video content in the stadium.

For the LTE unicast-signal the data rate ranged from 22 Mbps once the stadium was empty, to 4 Mbps while the stadium was busy. The average was around 12 Mbps during the show with measurements taken every two minutes and this manifested itself in buffering of the video streams.

The FeMBMS (5G Broadcast) signal was stable throughout a busy show in a live arena while the 4G signal fluctuated in line with audience members using their devices during the show. This shows that 5G broadcast would be a good solution for providing additional capacity for things like video content even in crowded areas, and that the quality would remain consistent.

CASE STUDY

This was a private 5G Broadcast network that could be rolled out at live event venues. The premise being that venue owners can use the broadcast network as a way of delivering a suite of content to fans and potentially other venue equipment such as big screens. During the trial there were 6 channels of content delivered to the VISTA application, these were:

- One channel containing “Special behind the scenes content” supplied by MK Dons. This became a replay or delayed live channel during the game.
- One channel English Football League live stream of the game.
- 4 of our cameras in the stadium shown in Figure 7. The 4 positions were chosen to be able to look at almost any area of the pitch and the action. Two cameras were manned and two had some remote control over iris, focus, and zoom.

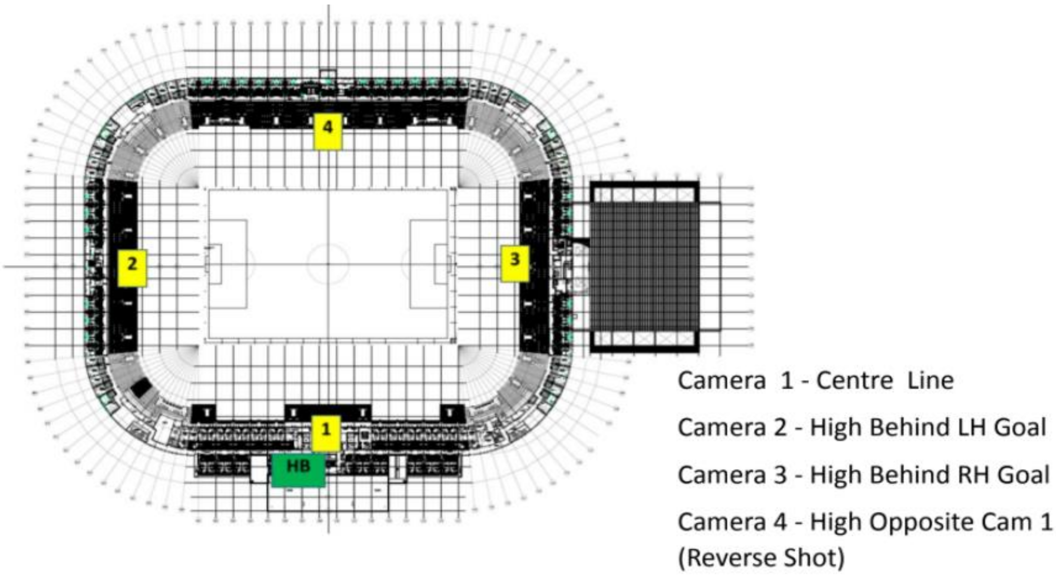

FIGURE 7 - CAMERA LOCATIONS

CONCLUSIONS

Reaction to the tests and trials was good. Users were pleased with the in-stadium service and focus groups supported the assertion that sports fans would pay for this type of service.

The VISTA Sustainability Report suggested that both in-stadium and wider distribution services are commercially viable even with relatively low audiences (~30K) and less than £5/monthly subscription for the Football App or around 8% top-up to ticket price for the Motor Racing app.

The project has achieved great success in working with Qualcomm to realise the first 5G broadcast chipsets which have been implemented in reference devices obtained by the VISTA project.

The project has also generated interest with major sporting events interested in doing trials with a view to live deployments.

Next stages are to continue with further showcases of the 5G broadcast solution with a view to bringing in stakeholders who would be key to bringing the solution to market. These are handset OEMS, more mobile network operators, and content owners.

The overall solution is around 18 months to 2 years from being commercially ready, but the project has unlocked a key impasse with the chipset availability.

The ‘journey’ was successful; however, it’s worth mentioning some of the lessons learned:

- Having an MNO involved is useful. The spectrum they bring is compatible with current handsets, and they’ve got one eye on integrating FeMBMS as the core network.
- Handsets are key. Samsung were involved at the start but failed to deliver FeMBMS/DASH capable handsets. Qualcomm have already produced a demonstrator unit (shown at this year’s MWC in Barcelona). We had to make do with SDR.
- The Qualcomm devices that were shown at MWC were configured with a mode of FeMBMS where only a selection of features are supported. Those devices can operate in bands 600 MHz, 700 MHz and 800 MHz.
- SDR does not perform well at 10 MHz bandwidth. It needs a lot of processing power making the receiver relatively expensive.
- The 5G-MAG OBECA FeMBMS receiver is fine for lab testing, but it’s got a way to go before it’s consumer-ready.
- Affordable 5G testing equipment doesn’t really exist. We were fortunate to have Rohde & Schwarz as part of our team.
- The application, whilst suitable for trial purposes, needs several enhancements to make it commercial grade.
- Containerised MEC encoding was not without its difficulties but proved worthwhile.
- The low-cost broadcast contribution system worked well.
- Choose equipment carefully (some network switches work better with media than others).
- We’ve intentionally kept marketing information out of this paper; those interested in the exact equipment, methods, and systems used can refer to the VISTA, Ateme, Rohde & Schwarz, and Ori sites.

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