Title	**ONP Final Project Report -ONE4HDD**
Versions	**V.1**

ONP Final Project Report: This report is expected to be publishable externally and provided to DSIT in an accessible format. The details are outlined in point 98 of the "DSIT Guidance for Live Open Network Projects". This template looks to outline the key sections we'd expect to see in projects final reports and provide prompts and guidance around the content for each section.

NAME OF PROJECT 5G ONE4HDD	
List of partners	Ateme, DTG (lead), Imaginary Pictures, Telefonica, University of Surrey
Total funding amount	£2,359,809
Locations	UK wide

Executive Summary

Maximum word count: 300 words

Live events currently provide a real service challenge for mobile network operators, with demand for data being particularly problematic at key moments, meaning that fans cannot access content. The investment required to overcome this issue by increasing bandwidth does not stack up financially as the venues are not in permanent use.
The 5G Broadcast technology and mobile cell deployment system that ONE4HDD uses overcomes this problem, as it comprises a quick-to-deploy mobile capacity combined with mobile broadcast technology. This means that capacity can be delivered as and when needed and video can be streamed from one source to many users. rather than one to one, meaning that the quality of service is maintained regardless of the number of users.
5G Broadcast technology can provide a richer live experience that will include: - multi-angle views of the action; views from areas that cannot be seen or behind the scenes; and additional information about the event.
This means that with 5G Broadcast technology fans can all access the same content and information at the same time, getting them even closer to the action. Combined with having reliable mobile experience for sharing photos, staying in contact with friends maximises and enhances their enjoyment of the event at that moment.

Deployment Summary

Maximum word count: 500 words

The Project's methods and deployment approaches were as follows:

(a) conducting extensive testing and demonstrations of the Project's solution in various HDD environments to showcase its performance and reliability;
(b) carrying out measurement and analysis of network performance of Open RAN technology, providing comparisons to proprietary RAN technologies;
(c) implementing a comprehensive cybersecurity framework to ensure the security and privacy of user data; and
(d) delivering a business case analysis that showcases the economic and operational benefits of the solution for mobile network operators and end-users.

To achieve this the consortium is made up of experts across the mobile and broadcast industries, specifically: Ateme, Imaginary Pictures, DTG (project lead), University of Surrey, VMO2 (technical lead), with support also from Rohde & Schwarz as a supplier of 5G Broadcast equipment, and Fraunhofer for delivering personalised audio.

The concept is simple; the use of a 5G Broadcast layer of coverage at stadiums provides capacity for event/venue owners to deliver content directly to fans' devices. This is supported by a "Mobile Cell Deployment System," which is a small cell system designed for special events coverage and capacity. This is delivered using a Mitsubishi Shogun equipped with a pneumatic mast, a robust DC power supply, a backup generator, and Cellxica M3Q and M5Q base stations

To test this the project has carried out several live demonstrations building from British Drone Racing championships with <50 spectators to the British Superbikes season finale at Brands Hatch with over 10,000 attendees.

Events were combined with customer focus groups to assess the commercial opportunity and to trial the technology, as well as technical measurements on the 5G network performance to compare the ONE4HDD solution with existing coverage.

The culmination of this is the project's sustainability report which has outlined an addressable market in the UK of up to £27m through supporting live events such as Horce racing, Cricket, Motorsport, Golf, and Festivals.

Results and Benefits Achieved

Maximum word count: 500

The results gathered from the project were based on the following benefits:

- *Improving mobile capacity in HDD environments*
- *Cost effective network deployments for mobile operators*
- *Enhanced market opportunities for venues*
- *Better security for content being sent over mobile multicast*
- *Enhanced mobile experience for fans at live events*

In response to all of these the project has been carrying out demonstrations and tests to measure the benefits.

Key findings of this are
Improving mobile capacity in HDD environments – ONE4HDD project deployed its cell on wheels using CellXica M3Q and M5Q base stations delivering mobile capacity at HDD events. As part of the testing, customer experience testing was carried out with R&S to measure the performance of the cell on wheels as well as the existing coverage provided by the 4 main MNOs. The measurements were made using a specialist backpack containing a framework with 9 mobile handsets making regular contact with the mobile networks, the results of which were then analysed using internationally standardised measurement metrics for voice, data, browsing etc. The measured metrics were things such as throughput UL/DL, browsing success rate, reliability i.e. measurements that quantify the overall experience for the end user in trying to access services. The results were that the CellXica equipment was able to provide robust performance which was comparable to the existing services provided by the 4 main MNOs – providing confidence in alternative RAN vendors. Additionally, the cell on wheels was completely standalone with Satellite backhaul over Starlink, its own power generation, and could be deployed in under 45 mins. This robust performance was replicated across all the metrics and provides confidence to MNOs of new RAN vendor equipment that can be deployed for HDD environments.

The project also compared the costs of deployment in terms of the totals for deploying the cell on wheels as a service at live events. This was measured by using CAPEX costing for providing mobile capacity for an example live event taken from real-world deployments by VMO2. The costs for then deploying the Cell on Wheels solution at the live demo events were calculated and scaled so that the capacity was equivalent to the VMO2 macro cell example. This enabled a like for like comparison of what it would cost to provide the equivalent capacity using the ONE4HDD flexible solution as to the fixed solution provided to live events already. The costs were comparable to existing macro cell solutions but with the advantage that they can be deployed in smaller, targeted ways, providing venues with flexibility as to how much they want to spend on coverage and how they can plan to cater for attendees.

In addition to mobile capacity and coverage, the project deployed a 5G Broadcast solution at Brands Hatch to provide fans with an opportunity to get closer to the action. This delivered live streams of the races in near real-time which provided selected fans the opportunity to keep up to date with the race action even when the riders were out of sight. Other features that were demonstrated were inclusion of rider statistics, behind the scenes content, personalised audio provided by Fraunhofer's MPEG-H technology. The trial was supported with 5G Broadcast enabled Xiaomi 13 handsets provide by TDF in France which were used during trials at the Paris Olympics. To secure the content, protect rights holders, and provide opportunities for tiered services such as premium or

ad-funded, the University of Surrey carried out testing of multicast encryption on mobile networks with logical key hierarchy that can be used to include or exclude users from the services with very little network overhead.

The project organised a customer focus group to try out the equipment to build on earlier customer focus groups held at the start of the project which were entirely conceptual i.e. the participants just had the concept explained rather than being able to try it out. The aim being that the focus group's willingness to pay and perception of the technology will have improved over the course of the project from concept to reality.

The feedback from customer focus groups using the technology was extremely positive where the challenges of watching motorsports were described as ***"It's always a great day out, but you do come away thinking that you only really saw about half of each race..."***
With the 5G Broadcast app providing "obvious benefits" such as :

- *greater engagement: "Chance to get to see behind the scenes, like the pits"*
- *clearer view: "Able to see stuff you can't normally see" and "Viewing out of reach places"*
- *More fun: "Choosing different angles/viewpoints" and "Zooming in and replays"*

The project's Sustainability report has highlighted that outside of the top tier of stadia in the UK, many struggle with the commercial reality of providing coverage and great engagement with fans and the combination of the solutions trialled at 5G ONE4HDD have a large addressable market of live events totalling up to £27m revenue annually.

A further benefit measured was the potential market opportunity for live venues by deploying the 5G Broadcast solution at an event to provide enhanced fan experiences. This was measured by taking data from current smart stadia revenue for an average UK stadium. Market research and validation was then carried out to understand the addressable market for 5G Broadcast solutions which factored in things like the number of events held annually, the existing smart solutions, the average revenue at the events, and the willingness for users to make use of the types of features that could be provided by the 5G Broadcast solution. The results showed an addressable market of between £3.8m and £27.8m depending on the % uptake of the fans attending and the price of the service that could be added as an addition to the ticket cost.

The last benefit was related to security and measured the additional overheads and delays caused by including multicast content security in the workflow to demonstrate that this was negligible and was much better than the overheads and delays added by current methods of encrypting content and providing conditional access. This was done using simulation software, OMNET++, and network monitoring tools such as Wireshark to set up scenarios where certain cyber-attacks were implemented, or content access scenarios were demonstrated for large crowds. The results showed that using DTLS encryption and Logical Key Hierarchy (LKH) for managing access to content in large

crowds caused meant that network delay remains low independent on how many people need to be managed i.e. how many people you have trying to access the content over 5G Broadcast. This contrasts with flat key where the delay increases in line with the increase in attendees

The 5G ONE4HDD approach to security has been of benefit and of value to the consortium because adding a security layer of using common tools such as TLS or DTLS (in unicast setting), enhances the authentications and authorisation of the multimedia content entering the mobile operator network. It also protects against illegal content distribution and other attacks such as Denial of Service (DoS). The LKH access control methodology provides a practical way for managing access to content in large crowds, paving the way for commercial opportunities with tiered levels of funding such as premium access.

Security

Maximum word count: 500 words

Summary of the projects approach to security
This should be a publishable summary of the security report touching on the ambitions outlined in the security strategy, best practice, standards testing, and results and lessons learnt. This will complement the separately required final security report.

The security strategy document for the 5G ONE4HDD proposed a novel solution to optimise mobile network performance in High Demand Density (HDD) environments such as music festivals, sporting events, and major public gatherings. The aim is to design and deploy a Mobile 'Cell on Wheels' equipped with Open RAN (ORAN) technology or the equivalent tier 2 RAN equipment.
At the heart of this project, there are several multicast broadcast technologies such as the 4G enhanced Multimedia Broadcast/Multicast Service (eMBMS) and the 5G Multimedia Broadcast Multicast Service (MBS). It supports content distribution to a wider audience via; a broadcast and/or multicast distribution model, providing high spectral efficiency. As such, the large-scale distribution of real time streaming IP packets can be broken down into two steps:

- *First step is the wide area distribution using IP multicasting.*
- *Second step is delivery to customers in the RANs using broadcasting (or multicast if possible).*

Therefore, multicast security provides a flexible way to manage security and key management for such services. The project adopted the European Union Agency for Network and Information Security (ENISA) guidelines on the threat assessment for 5G mobile network and using the related 3GPP specifications. The security recommendations for the major components in 5G ONE4HDD are:

1. *Between the MEC and eMBMS (or MBSTF in MBS): The Transport Layer Security (TLS) / Datagram TLS (DTLS) are recommended. This will provide access control*

(authentications and authorisation) plus confidentiality and integrity protection. This approach is compliant with the ORAN Alliance recommendations. Optional security is also possible for other unicast hops in the network such as using TLS between content provider (e.g. cameras) and the MEC.

2. *In relation to the secure broadcasting/multicasting, DTLS is recommended as the end-to-end security solution between the Content provider and a group of UEs.*
3. *Regarding key management, the use of the flat-key system is recommended for static groups (fixed membership) and LKH is recommended for large dynamic groups (changing membership). It is agnostic to the 4G/5G technologies. It can also bridge the security gap between mobile and broadcast operators.*

The security research focused on secure multicasting and broadcasting. Looking ahead towards 6G, secure multicasting/broadcasting will need to be dynamic and scalable for large groups that could be distributed in wide areas. This also might include 3D networks (including satellites, drones and High-Altitude Platforms, HAPS). The ONE4HDD research is focused on using Logical Key Hierarchy (LKH). This research caters for future use cases where multicast groups could span large geographic areas (e.g. multicast users are spread through several major cities, like a popular football game) and multiple administrative domains (e.g. multiple mobile operators and cloud providers).

High level summary of project costs

Maximum word count: 500 words

High level summary of project costs (to DSIT and project participants). (Equipment and deployment costs of any networks are also of interest)

The total projected expenditure is £2,359,807, with the highest costs attributed to labour, subcontracting, and overheads across five project partners. DSIT provided £1,467,955 in funding, while partners contributed £891,852. The spending pattern shows a relatively consistent distribution across claims, ranging from £258,371 to £452,697 in gross costs per claim. Ateme holds the largest share of the gross budget at £685,542, primarily due to significant labour costs (£517,503). VMO2, with lower labour costs, incurs the highest subcontracting costs (£373,643), making it the second-largest cost contributor at £633,079. Digital TV Group has substantial expenditures in labour (£301,004) and subcontracting (£164,293), totalling £598,769. Imaginary Pictures has the smallest expenditure at £60,977, with labour being its primary cost driver.

The significant labour costs reflect the extensive expertise involved in developing and shaping the project, which was delivered on time and within budget. Spending on labour ensured that the bulk of the expertise remained within the project, providing better value for money (VFM) for DSIT in terms of benefit realisation and continuity. The use of some subcontractors was beneficial, as they were able to deliver equivalent work at a lower cost, providing better VFM.

Equipment purchased specifically for the project amounted to £87,000 (5% of total funds) and included a satellite dish for high-speed, low-latency internet essential for maintaining seamless

operations for the cell on wheels, camera kit, and server. Capital expenditure was only 5% of the total gross costs, with 2% funded by DSIT and the remaining 3% by VMO2 and Ateme (both of whom received the lowest funding subsidy available at 40%). The expenditure was fully written off during the project due to their bespoke configuration.

In conclusion, the project successfully managed a total expenditure of £2,359,807, with significant contributions from both DSIT and project partners. The strategic allocation of funds, particularly towards labour and subcontracting, ensured the project was delivered on time and within budget, reflecting the high level of expertise involved. The careful use of subcontractors and targeted equipment purchases further enhanced value for money, demonstrating effective financial management and resource utilisation. Overall, the project achieved its objectives efficiently, providing substantial benefits and continuity for DSIT and its partners.

Project Highlights

Maximum word count: 500

The project has had many highlights over the 18 months of work that has gone into it. The standout achievement is the live deployment of the 5G cell on wheels and 5G Broadcast technology at Brands Hatch during the Superbikes Season Finale. This required a huge amount of coordination to not only deploy the equipment but gain rights to use the content from Warner Bros Discovery, get access to the venue, get spectrum licences, bring in a customer focus group, arrange for the customer experience testing during the event, arrange for 5G Broadcast handsets to be delivered from TDF in France following the Olympics. TDF later commented on the success of the trial saying:

"So glad to see 5G Broadcast landing ground in one more country in UK GB after large scale user experimentation held in France FR during Paris 2024 Olympics"

"And very pleased 🤝 to support 5G ONE4HDD with TDF Xiaomi France smartphones."

"Let's be always the first one to see goals and discover champions crossing the line with #5G #broadcast. Whenever. Wherever. Whatever you do."
Jerome Andres, Marketing Director, TDF

Overall, a herculean effort for the whole project team involved which was rewarded with a successful demo and a great day out watching some spectacular racing.
In addition, the project benefited from great collaboration with a range of partners over the course of the project such as R&S, Brands Hatch, Jigsaw, Horse guards, and as already mentioned Warner Bros, Xiaomi, and TDF, and was able to successfully demonstrate the way the technology could benefit many smaller events across the country. This included working with the likes of the Weston Park Airshow and the British

Drone Racing Association, and really captured democratizing of mobile support for live events.
Lastly, working with DSIT and the grant funding they provided was a great benefit and enabled the project to carry out the research and development needed to deliver the demonstrations. Their support with contacts, ideas, and the project framework was a real help.

Project Conclusions

Maximum word count: 500

The project aims were to investigate the use of tier 2 RAN vendors for supporting high density deployment scenarios and inclusion of enhanced fan engagement via the latest 5G Broadcast technology. The conclusions from working with live event venues such as football stadia, rugby stadia, venues for live shows and exhibitions, as well as the research carried out for the Sustainability report, the customer focus groups, and the customer experience measurements that were made, were that HDD mobile deployments remain a significant commercial challenge to the vast majority of venues, providing enough capacity to support a large number of attendees on an intermittent basis of time is not commercially viable. From the measurements made, some solutions such as carrier aggregation reduced the impact of network congestion in busy areas and further improvements could have been through greater use of 5G NR. However, the project's use of 5G SA proved advantageous as the conclusion of the R&S customer experience testing was that the Wavemobile network (the name of the network used by ONE4HDD) had the best results in terms of performance during network congestion.
As such, moving to new 5G networks could significantly improve the cost model for supporting live venues with HDD events.
From a fan engagement point of view, many venues had tried with limited success to support fans with apps which could be used for video and audio features. From the tests and feedback back gathered during the project these provide a poor customer experience due to network congestion. However, fans were keen to have access to additional services and features from the venue and expressed a willingness to pay for these as part of ticketing. The GSMA carried out a 2024 survey across eight of the world's largest mobile markets finding that 25% of smartphone users consider enhanced user experiences in venues an attractive proposition that they might be prepared to pay for.
The level of features depended on the type of event e.g. at a music gig people were less interested in watching live video content as they would rather watch the act but were interested in behind the scenes and exclusive content to watch before the gig/while waiting for it to start. Distributed events like festivals, athletics, motorsport, golf were of the most interest and provide clear use cases to keep across the live action. 5G Broadcast is a cost effective and easy to deploy solution to provide this and is enabled in the firmware of most mobile chipsets. The project used Xiaomi handsets during its demos and there is much interest in Europe for the use of 5G Broadcast however the challenge now is to follow up such pilots by incorporation of the capabilities in services and more handsets, even as premium features. This is a natural use case for operators

which can either serve venues over their own public 5G networks or deploy a small private 5G network in collaboration with the venue owner. For large area networks, A 5G Strategic Task Force has since been set up in Europe to drive forward deployment of 5G Broadcast with TV Broadcast Network Operators and coordinate efforts with mobile handset vendors. DTG is going to support this by setting up a 5G Broadcast working group to coordinate activity and share knowledge from the ONE4HDD project members as well as UK TV Broadcast Network Operators .

Next Steps

Maximum word count: 500

The project has outlined several follow up steps which would enhance the features and functionality available with 5G Broadcast and further optimise the use of the cell on wheels 5G network – these are:

- ***Monetisation:***
  - *Integration of dynamic ad-insertion, targeted advertising, and personalised audio within the 5G Broadcast framework, creating direct revenue streams and added value for venues and rights holders.*
  - *User trials of the enhanced 5G Broadcast functionality and monetisation features to validate commercial models*
- ***Scalability:***
  - *Adoption of new standards, including AV1 codecs for bandwidth efficiency, multicast HARQ for robustness, and seamless handover between multicast and unicast.*
  - *Validation of scalable codec technology to support diverse use cases across live video deployment.*
- ***Performance:***
  - *AI-Driven Optimisation: Using RAN Intelligent Controller (RIC) to deploy AI-driven RAN optimisation to enhance performance in HDD environments.*
  - *Non-Terrestrial Networks (NTNs): Developing the project's implementation of satellite and terrestrial backhaul solutions through working with the TUDOR project to improve resilience and scalability.*
- ***Security:***
  - *Quantum Safe Cryptography (QSC): Implementation of advanced security protocols such as FALCON and CRYSTALS-Kyber to enhance data protection for sensitive applications (e.g., defence, government, business) and move these technologies towards commercial adoption.*
  - *Dynamic Threat Response: Development of Quantum Machine Learning (QML) for intrusion detection systems (IDS) and seamless switching between classical and QSC algorithms based on threat levels.*

The project is looking to continue the work achieved in ONE4HDD by exploring these options above and continuing engagement with live venues with a view to creating a commercial pilot. This will be led by DTG through a new 5G Broadcast working group.

Media Library

Project information website including news section here.
Explainer/project sizzle video reel here.
DSIT video case study here.
Social Media here.
Media library here
Contains:

- Project photography
- Brand logo files
- Partner logos
- Brand Guidelines
- PPT template