Virtual 360° Video Training

5G-ENCODE 3.1.1

VIRTUAL 360° VIDEO TRAINING DEMONSTRATOR

The Virtual 360° Video Training Demonstrator case study is split into 2 phases; phase 1 being a 4G network demonstration with results published in this report, and phase 2 demonstrating the solution on a 5G network, which will be published towards the end of 2021.

Industry Challenge

Effective knowledge transfer through training is a core part of people development. Classroom and workshop training scenarios where both the Trainer and Trainees co-locating within the same practical demonstration space are a proven method to enable this. However, this scenario can prove costly (due mainly to travel, facilities and accommodation costs) and the impact of COVID has made face to face training even more challenging, if not impossible for companies to deliver.

While current distance learning options are already available, and internet-based courses and systems to support students offer a solution, the capability to engage effectively with the Trainer and deliver more practical aspects of a course is difficult. More immersive distance learning solutions are proposed to address this industry challenge.

This VR immersive training demonstrator will showcase the latest 360-degree video streaming and virtual / distance learning solutions. It will deliver practical training of the manual layup of carbon composite materials, a module of the National Composites Centre (NCC), 'Fundamental to Composites' training course. The solution aims to provide distant learning Trainees with the same real-world experience as if they were on site with the Trainer.

Setup, Architecture and Innovation

A TECHE 360Anywhere 360-degree video camera is mounted into the Training Cell at the NCC main site with a view of the demonstration area. The course Trainer stands behind a workbench in front of the camera. To the side of the Trainer, a separate mobile device allows the Trainer to manage fixed media content which is overlaid onto the streamed video.

The live video stream is transmitted to the Streaming Server via a wired network connection. The Streaming Server manages the live video feed and transmits to a Caching Server which receives the live video stream in a one-to-one relationship, and manages the calls to view overlays on the video stream. The video stream is transmitted to the Trainees via a 4G Small Cell, where each of them can view the training course via VR Headsets and tethered 4G Handsets.

The 360-degree video camera feed allows the individual Trainee to independently pan around the demonstration giving them the flexibility of a real-world view. A significant element of progress will be the inclusion of two-way communication, allowing Trainees to communicate with the Trainer.

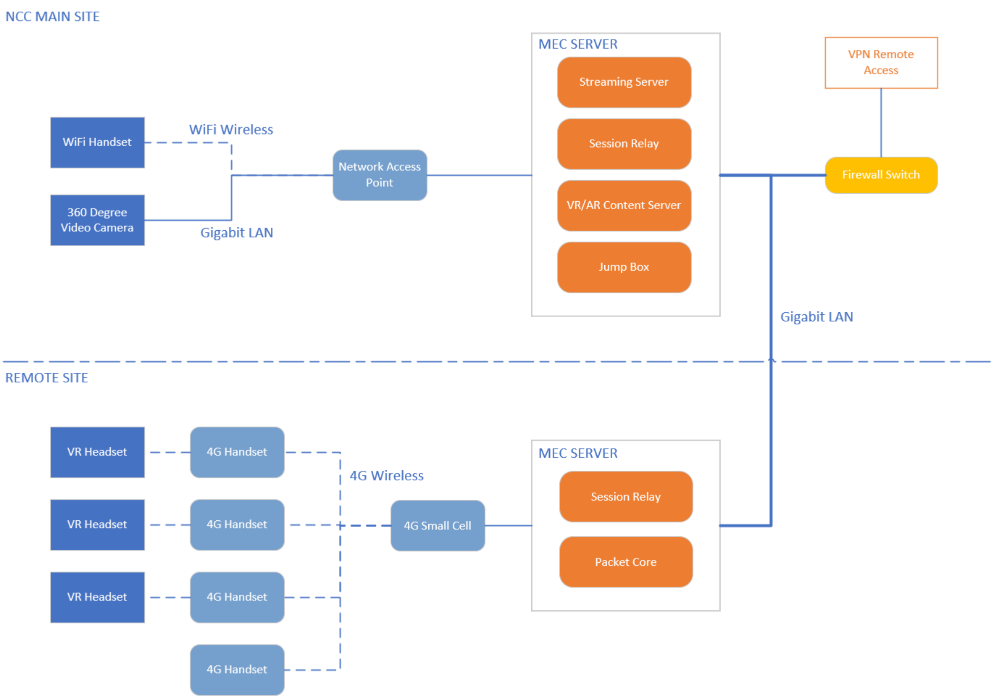


Figure 1 - The Architecture of the solution

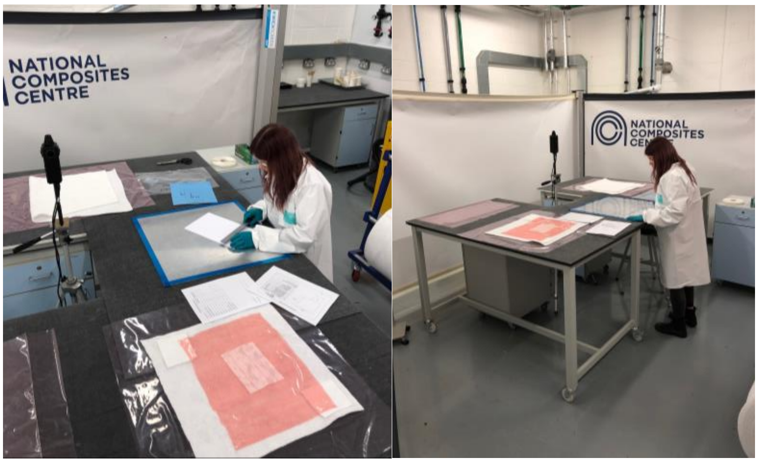


Figure 2 - The demonstration setup with the 360-degree camera and the Trainer presenting the training course

Figure 3 - The Trainees watching the training course video stream

Phase 1 Outcome and Results

Phase 1 of the case study demonstrated the capability training course video stream across a 4G network to set a benchmark for the video latency, bandwidth, and useability.

The plan was to live-stream concurrently to 6 mobile phones, the 360 degrees training video at 3840x1920 (4K) resolution via low latency P2P (Peer to Peer) Streaming. For 4K video, the encoding bitrate was planned to be 20Mbps to get a crisp looking image without artifacts. We would adjust the bitrate according to network conditions and speed available via the 4G antenna to get a stream over the network and the 4G radio to the 6 mobile phones. The network requirements for 6 devices at 20Mbps is 120Mbps.

User Feedback

The documentation of the users' experience is a really important part of the project, as it provides a clear view on the users' needs and can therefore influence the product/ service development. As part of the 5G-ENCODE - virtual 360° video training demonstrator, a focused set of responses was collected from an online questionnaire which documented the user's feedback. In this section, the methodology and the results of the user experience survey will be presented.

For the purposes of the lab-based trial, after their experience of the service, the participants were asked to fill in a focused questionnaire that aimed to capture and evaluate their experience. The scale used in this questionnaire focused on the following topics:

- Attractiveness of the product/ service/ experience
- Efficiency of the product/ service/ experience
- Novelty features
- Overall feedback

It is clear from the participants feedback (see table below for the results) that the service provided was not at a satisfying level. This proves, from a user's point of view, that the 4G set up is not capable of performing with the necessary quality of service. The poor performance of the network and the poor picture quality (interpreted as high levels of latency) have negatively affected the users' experience, the knowledge transfer efficiency and the communication with the Trainer. However, the potential and the novelty features of the service were acknowledged, which means that if the network performs better and the service is stabilised, the experience will probably have a totally different impact.

These results are very interesting and will prove useful and of value, when compared with future feedback collected during the next stages of the project.

Participant Survey Results

How satisfied were you with the quality of the live stream experience?	50% Extremely Dissatisfied 50% Dissatisfied
How would you rate your ease of communication with the Trainer?	50% Extremely Dissatisfied 50% Dissatisfied
How would you rate your perceived latency when communicating with the Trainer?	100% Bad, lots of latency
Please rate the knowledge transfer efficiency of the experience	100% Partially Efficient
Please rate the usability efficiency of the experience	100% Partially Easy to Use
Please state/ select the novelty features	50% Responsive Experience 50% Cost effective (saving travel & training costs)
Would you be happy to use AR/VR for training instead of on site?	50% Yes / 50% No
Any overall feedback for the experience? • Using the 4G was very lag intensive I feel as though my understanding of prepreg helped me understand the stream • I enjoyed this experience and I can't wait to try it after its changed to the 5g network	

Networking issues and lessons learnt identified through phase 1 include:

- The configuration of the network infrastructure took longer than expected to resolve, which impacted on the time available to test prior to the demonstration day. These delays where caused by;

    - The extended time taken to configure Dynamic IP addressing on the 4G network to allow the 360-degree camera to be assigned an IP address.

    - The configuration of the Virtual Machine on the MEC server to enable it to stream the video output to the handsets and the challenges of remote working across a VPN access point.

- Starting the live stream we set the camera bitrate to 1Mbps, increasing it in increments (steps 1Mbps / 2Mbps / 4Mbps / 6Mbps) testing out the network and the 4G radio to the point where the video stream did not reach the handset. The break point was reached at 6Mbps. The bitrate was scaled down to 4Mbps so it would reach the 6 handsets. The 2-way communication along with explanatory overlay still images were tried, but this impacted the bandwidth of the overall system and subsequently the video stream. This functionality was switched off to maintain the visual stream and not compromise the quality even further.

- The aim for phase 1 was to use the Oculus GO VR headsets to visualise the 360-degree video stream but challenges with tethering the headsets to the Samsung 4G handsets meant that it wasn't possible to use the headsets on the demonstration. The challenge was getting the headset to connect to the 4G handset when it was set up as a mobile data access point. It was possible to connect a laptop to the 4G handset mobile data access point but the headset kept coming up with invalid login access details for the mobile Wi-Fi. The headsets however are configured to work directly with Wi-Fi networks. Headset compatibility may be a major blocker for the 5G implementation.

- The images of the streamed video at 4Mbps, as seen on the Trainee's device below show the poor quality image which would appear is due to the low bandwidth. The bottleneck of the system was the 4G radio and its available spectrum that could only reach up to a theoretical speed of 37.5Mbps.

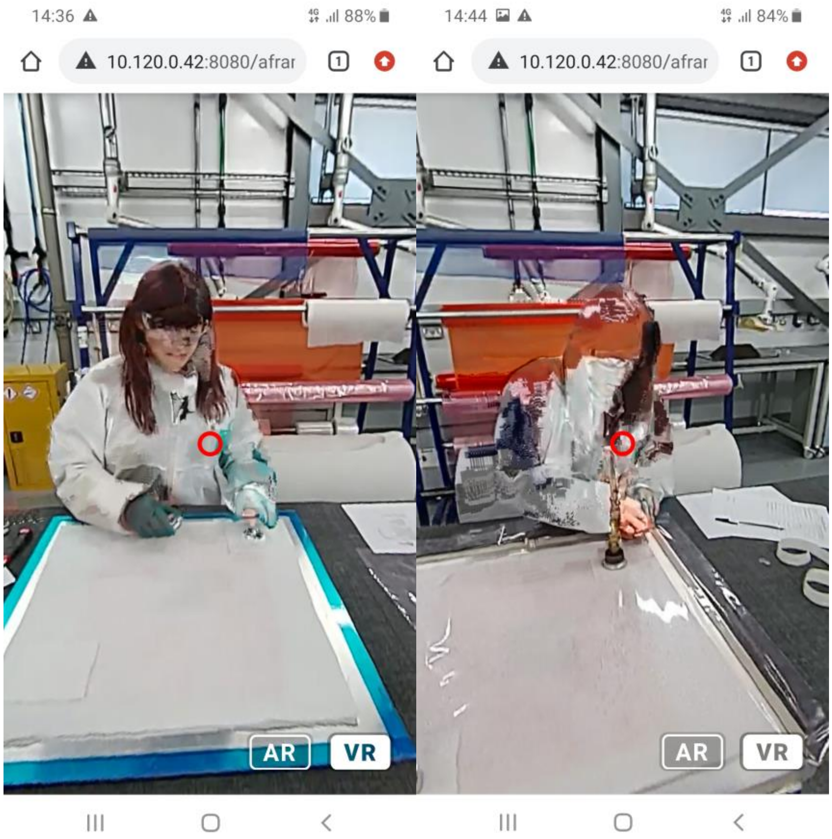


Figure 4 - Images of the training course video stream on the Trainee's device

For the full 5G trial we plan on running 12 devices concurrently at 20Mbps with a target network capacity requirement of 240Mbps.

The full 5G radio will give us 960Mbps that we can use to reach the target 20Mbps per device stream.

Network Traffic Statistics

The figure below denotes the number of active connections coming into the server and the number of active outgoing connections i.e. 6x Trainees connecting at 1:30 and ending at 3:00.

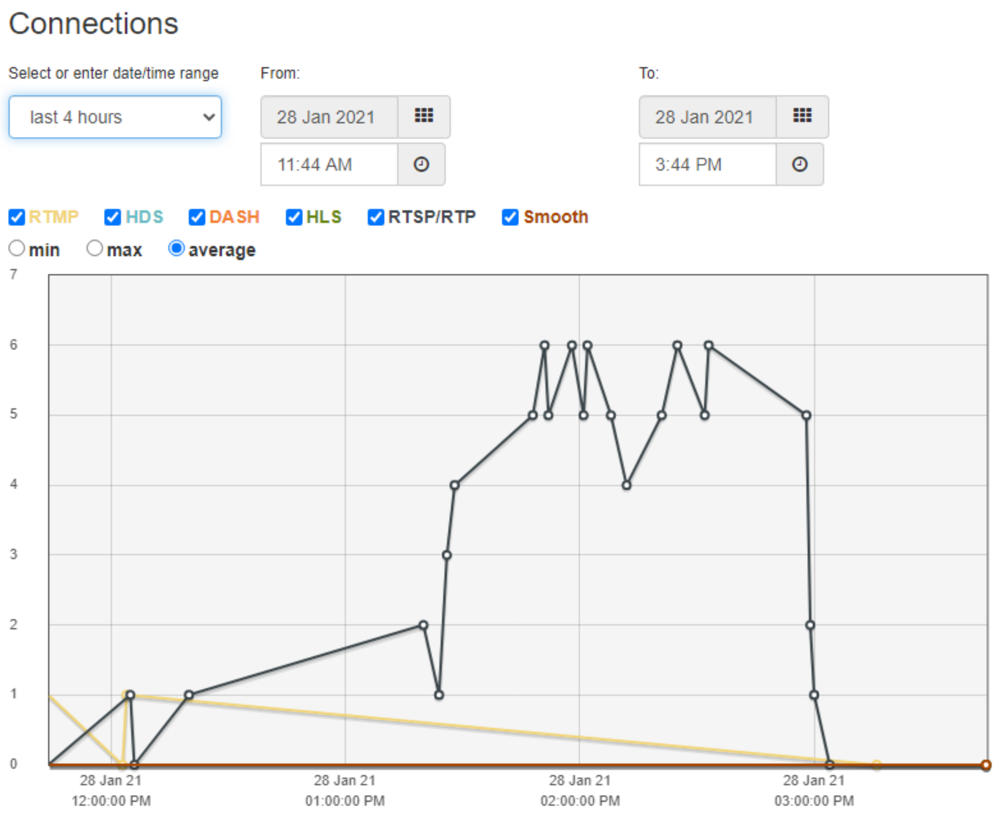
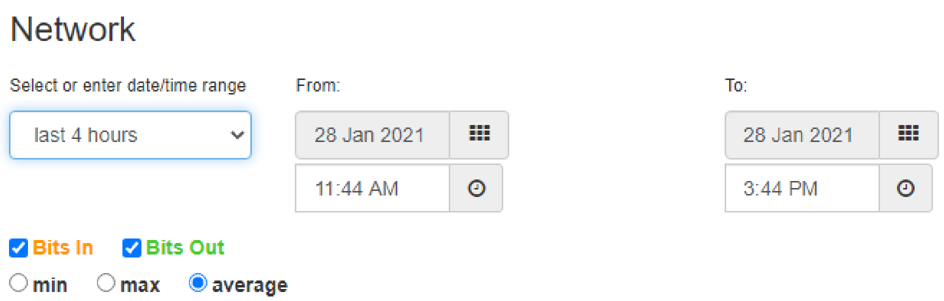


Figure 5 - Active incoming and outgoing connections through the server

The data in orange below describes the speed (measured in 'megabits per second') or bit rate of the incoming stream towards the streaming server; i.e 360-degree camera to the streaming server (streaming at 4Mbps), whereas the data in green denotes the outgoing streams in total from the streaming server; i.e the total stream traffic leaving the streaming server toward the client devices which are the 4G handsets (6 connections x 4 Mbps = 24Mbps).

- At 60Mbps is the base line bitrate of 10Mbps for 6 users.
- At 120Mbps is the target bitrate of 20Mbps for 4K video for 6 users.
- At 240Mbps is the target bitrate of 20Mbps for 4K video for 12 users.



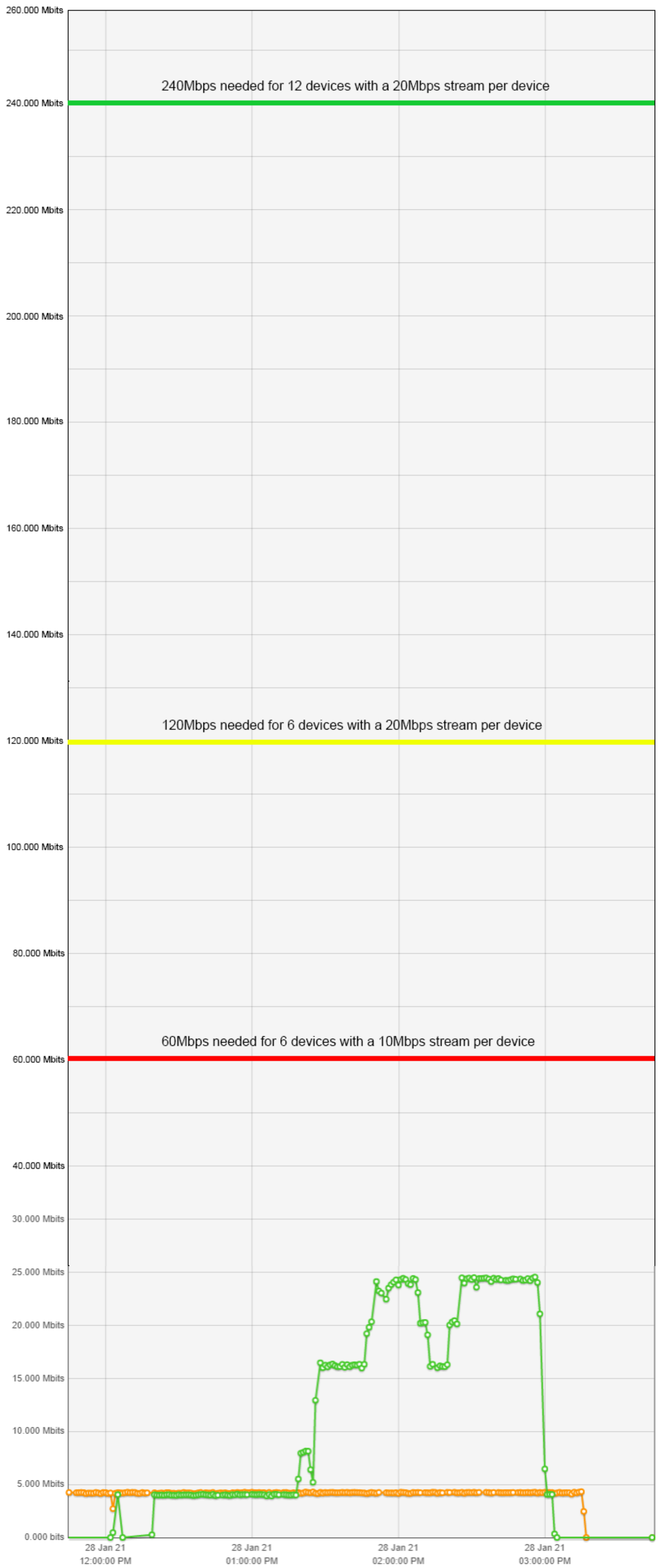


Figure 6 - Speed or bit rate of the incoming stream towards the streaming server

Industry Enhancement

Phase 2 activity will establish a 5G network and builds on the lessons learnt from phase 1 to demonstrate the enhancements gained from low latency video streaming and useability, which will be compared to the 4G network. The impact to industry is expected to be;

- Significant improvement to distance learning activities and opportunities
  - Ability to develop remote learning capability for both internal and external customers.
  - The ability to have two-way communication with an expert helper.
  - Video streaming over low latency wireless networks allows external participants to experience factory/manufacturing processes from remote locations.
- Significant flexibility to run training scenarios remotely and in multiple locations using the same kit
  - Low latency wireless networks allow the flexible positioning of camera systems in a manufacturing environment for both technical training and 'walk the factory' virtual tours.

About 5G-ENCODE

The 5G-ENCODE Project is a £9Million collaborative project aiming to develop clear business cases and value propositions for 5G applications in the manufacturing industry. The project is partially funded by the Department for Digital, Culture, Media and Sport (DCMS), of the UK government as part of their 5G Testbeds and Trials programme. The project is one of the UK Government's biggest investment in 5G manufacturing to date.

The key objective of the 5G-ENCODE project is to demonstrate the value of 5G on industrial use cases within the composites manufacturing industry. It will also validate the premise that using private 5G networks in conjunction with new business models can deliver better efficiency, productivity, and a range of new services and opportunities that would help the UK lead the development of advanced manufacturing applications.

The project will play a key role in ensuring that the UK industry make the most of the 5G technology and ultimately remains a global leader in the development of complex composites structures using robust digital engineering capabilities.

The project will showcase how 5G features such as neutral hosting and network slicing can be applied to transform a private 5G network into a dynamically reconfigurable network able to support a wide range of applications (URLL/eMBB/MMTC) including industrial applications of Augmented Reality/Virtual Reality (AR/VR), asset tracking of time sensitive materials and automated industrial control though IoT monitoring and big data analytics. Such a dynamic network would enable new business models and creation of bespoke virtual networks tailored to specific applications or use cases.

The state-of-the-art testbed will be deployed across three sites centred around the National Composites Centre (NCC) in the South West of England. In support of the West of England Combined Authority (WECA) industrial strategy, the NCC plans to keep the testbed as an open access facility for the experimentation and development of new products and services for the composites industry after the completion of the 5G-

ENCODE project. The location and nature of NCC's business would ensure the creation of an industrial 5G ecosystem involving multiple industry sectors and SMEs.

The project consortium brings together a Tier 1 operator (Telefonica), leading industrial players (e.g. Siemens, Toshiba, Solvay), disruptive technology SMEs covering all aspects of network design, deployment and applications (Zeetta Networks, Mativision, Plataine), a world-leading 5G network research group (High Performance Networks Group in the University of Bristol) and the NCC representing the high value manufacturing industry.

For more information about 5G-ENCODE, visit; https://www.5g-encode.com/ or email info@5g-encode.com