5G Rural Integrated Testbed

D4.10 Interim Final Report

The ways in which users were supported throughout the trial, as well as feedback gathered, successes and challenges that arose from the deployment.

Acronym:	**5GRIT**
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1. EXECUTIVE SUMMARY

Working in conjunction with project partners to deliver objectives under a DCMS funded project to identify, trial and implement 5G technologies into rural areas attempting to extend the benefits into farming, tourism and rural broadband provision; this will be monitored and evaluated for performance statistics. Following an initial testing phase 1, the trial will be elevated into larger scale deployments to leverage volume from the solution and test its operational capabilities.

NB: both partners were also the key partners for WP 6 about network Technology – and many of the details about the performance of the technology are described in more detail in the WP 6 report. It was deliberately decided not to repeat large elements of the findings in both the WP 4 and WP 6 reports

1.1. Quickline

The rural areas for Quickline's [QL] testbed were identified as being furthest from the cabinet of unconnected properties, where traditional technologies have found it near impossible to reach with a superfast, reliable service, and provide adequate value added services to the end user.

Equally, it can be said that knowing a particularly challenging geographical area, the identification of potential trial / customers would also be relevant to their inclusion in the trial, and so this looks to trial capture from both perspectives.

In both scenarios QL worked with an enthusiastic and willing user base to install equipment, demonstrate its use, support their reported issues, evaluate and provide feedback on a regular basis; this feedback would be used as a means for continuous improvement to ensure the end user experience would be optimised, [given the technology readiness levels of equipment deployed] the overall objective of which would be to attain superfast internet connections into rural areas, the tourism industry and farming.

The phase 2 technology elevated use would only be pursued if sufficient technology readiness level (TRL) can be achieved, the results of which will be borne from the trial.

1.2. Broadway Partners

This report shows that despite the many issues with equipment availability and function there is a useful and potentially commercial opportunity for TVWS in rural areas. However, the spectrum interference experienced from TV antennae mean that suitable areas are very limited. However, it's a new technology and we are aware of equipment upgrades and revisions that potentially could eliminate/reduce some/all of the current issues.

Spectrum Sharing makes the most of that resource and is a well acknowledged requirement to deliver 5G long term. In 5G, sharing can be for seconds whilst an autonomous vehicle moves through an area, or for longer periods of time for various uses such as an event or concert.

It is a fairly new / maturing technology and in theory is almost tailor-made for a rural environment.

60GHz spectrum is utilised for short distance, high speed communication. Ofcom is in the process of clearing higher frequency to enable more high-speed access specifically for 5G fixed wireless access.

Owing to its propagation characteristics, most notably its oxygen absorption rate and susceptibility to clutter, it is questionable if the technology can usefully be utilised in a rural environment to deliver low latency, high speed performance – and Broadway has set out to answer that question.

2. INTRODUCTION

As part of the Department for Digital, Culture, Media and Sport 5G Testbeds & Trials Programme, this report will document the differing approaches adopted by Quickline Communications (QL)and Broadway Partners (BP) in relation to:

1. Equipment selected for inclusion in the trial,
2. Geographical areas selected with justification criteria,
3. Implementation processes,
4. Lessons learned and documented,
5. Conclusions and future works.

Given the differing approaches of both QL and BWP for the above aspects, this report will address these topics in two sections, leading with the outputs from QL, then those from BP.

The stage of completeness of the two partners differs due to their position with respect to the extension to the project:

- QL is running their network trials to the end of the 6-month extension and using the period as an extended trail period to determine the effects of seasonality of the network performance.
- BP is extending their trials by only 2 months to obtain customer data and feedback and then writing their final report. Thus, the completeness of their results in this report is limited.

As a broader reach to the project, the project also entailed the following requirements to assist in the support of overlapping work packages (WPs):

1. Supply and provision of equipment and technical consultancy to other members, to be considered as part of the trial, as well as its procurement to and from third parties were identified as necessary to facilitate their WPs.
2. Support across the end users [EU] regardless of technologies deployed to ensure their connections are performing optimally; at the point of installation and subsequent support visits, documented evidence would be gathered and used as part of the periodic reporting milestone process. Those customers who agreed to participate were introduced to members from Lancaster University to enable WP7 Monitoring and Evaluation and so allow their connections to be independently monitored to understand aspects such as speed, latency, and performance fluctuations in conjunction with aspects such as adverse weather.

2.1. Interface with WP 6 Reports

Both QL and BP are also key partners in WP 6 relating to network technology. BP in particular has written detailed reports in WP 6, which they have avoided duplicating in this report.

3. RESEARCH QUESTION

Can 5G deliver 30 Mbps broadband compliant with BDUK's state aid requirements in rural areas at scale?

There were two primary streams of work within **WP4 - Rural Broadband** (WP4) which were set-up to achieve the following:

1. 5G equipment evaluation:
    a. This aspect of WP4 involved identification of 5G technology and its providers who would be willing to participate in the trial, in terms of equipment provision and its ongoing support as and when technical support was required.
    b. The trial would focus on an initial phase which would document the equipment's deployment into the designated areas to determine support of each use case. Depending on success levels in the initial phase would determine whether the technology would be proposed for upscaling into larger phase testing and roll out to determine its capabilities under duress.
2. Customer identification and service provision:
    a. Given the service industry insight QL has with its established customer base, either current or prospective customers, it was in a position to use mapping technologies to determine whether a customer would be able to be supplied with a connection. A customer who would be considered a borderline connection was considered for inclusion into this trial, given that traditional technology deployment would be insufficient to provide a sustainable connection and quality of service.
    b. These factors are dependent on customer location, proximity to QL's distributed backhaul infrastructure, and finally the prevailing terrain challenges which intersect both locations of customer and mast, for example trees and buildings.
    c. In conjunction with the use case scenarios established at the offset of the project, QL identified differing usage profiles each of which has differing demand service requirements.

The secondary work stream included interaction with other members in the consortium to undertake the following:

1. Knowledge sharing
    a. Sharing experiences of activities undertaken with consortium members to limit the propagation of any future risks and issues, and to promote positive aspects of activities undertaken.
    b. In some cases, each WP has an overlap level with other consortium members for continuity etc. As by way of example, once a customer is installed with a 5G technology, they would qualify for inclusion in WP7 Monitoring and Evaluation, and so QL was able to pass the interaction with the customer across to Lancaster University in support of its WP Furthermore prior to any TVWS works being carried out in the field, an analysis of proposed areas was undertaken by KCL to determine spectrum availability, and so QL was in a better position to determine relative success

levels once the equipment was deployed, using pre-validated areas for spectrum availability.

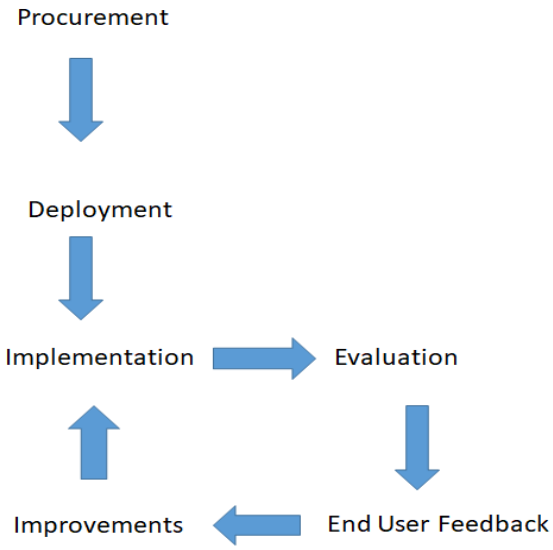
2. Documentation of lessons learned
    a. By using a centralised log, QL could document risks and issues to communicate throughout the consortium, as indeed could other members. Should issues become realised it becomes necessary to identify a way by which the risks can be mitigated by working in conjunction with the equipment supplier for support.
3. Equipment procurement
    a. To support other WPs that required equipment to be supplied, QL has some commercial arrangements with suppliers to facilitate equipment procurement, and so allow the third party to operate independently from QL and focus on delivering its WPs. A useful example of which is the works QL and BBSR undertook to provide equipment in support of its WP5.

Both work streams centred on identification of end users, and provision of equipment to facilitate an internet connection using 5G equipment. Any risks, issues and lessons learned throughout this process would be documented centrally and shared with other participating members.

Once QL had an opportunity to fine tune each connection, (a process which remains ongoing) regardless of technology deployed, the equipment would be considered to be proposed for further density-based phase 2 trials to determine its suitability in a harsher and more testing environment.

4. IMPLEMENTATION

The following activity loop has been used in the implementation of both TV White Space (TVWS) and 60 GHz technologies across the identified test beds. It allows QL to support the end users and provided a level of confidence that QL will continue to improve the service.



4.1. Procurement

Once the operational capabilities and limitations of TVWS equipment were understood with the supplier there were significant delays in importing the goods due to stock availability.

During this time QL entered further discussions with the equipment provider to ensure that sufficient planning was completed before any truck rolling exercises happened. Aspects of risk mitigation were undertaken, and customers were kept informed regarding timescales for delivery, and the requirements for distribution of signal through their enclave of buildings.

In regard to 60 GHz equipment, this was less of an issue given the presence of a UK equipment reseller and distributor; in this case QL was able to perform the field-based installations with greater immediacy and had the added benefits of greater immediacy of feedback from the end users.

4.2. Deployment

Deployment of equipment came in two phases; the initial phase being TVWS equipment which was installed in three locations, each of which brought a challenging environment and selection of use cases. One of the use cases has now been decommissioned as there was too much interference given the surrounding TV transmitters for it to remain a viable installation.

The 60 GHz equipment was selected for installation in a rural housing estate in a densely populated area to determine the achievable speeds, and equipment reliability.

In both technology cases, the variables of equipment, prevailing weather, locations, and installation would assist in supporting QL's view of technology readiness levels (TRL). The TRL for Quickline would be of sufficient stature as to consider it a viable inclusion in any further phase development works; in the case of TVWS it is QL's view that it is not of sufficient TRL however the opposite can be said for 60 GHz equipment, which we propose to include in a phase 2 test bed.

4.3. Implementation

The TVWS base station equipment was installed in areas were the broadband, farming and tourism use cases could benefit. Non line of sight being one of the key aspects of TVWS, it was chosen to test the viability of transversing hills and trees. In this case it was installed with relative success levels into Alston (tourism and farming), and Longhills, (rural broadband), delivering dual channel double digit speed connections, and as a result able to support the WAM application.

The 60 GHz equipment was installed into a housing estate which had suffered with sub 2 mbps ISP services and no sign of emerging fibre installation. We engaged with a customer champion from the designated area to advise that QL could provide a fibre fed wireless solution delivering either high double digit or triple digit speeds; it became evident that we would have a useful test bed to undertake the phase 1 trial. Indeed, the positivity of the end user feedback (speed tests and narrative, support tickets etc.) has been encouraging, even when taking into account relative storm damage which commanded site support visits for purposes of realignment.

4.4. Evaluation

In both cases of TVWS and 60 GHz equipment deployment, the evaluation phase is something that remains ongoing throughout the trial; QL has at all times, valued the feedback received from end users who have agreed to participate in the project. QL proactively contacts the customers on a monthly basis to request speed tests (See ***D7.5 Interim report on the systems being used to monitor the network and what issues have arisen***.) and any narrative feedback; equally, the customers are aware they can contact QL's support desk to provide feedback should any issues prevail.

The task of evaluation was undertaken by Lancaster University. Lancaster has supported and assisted QL throughout the project in identifying issues on the deployed networks, as and when areas are failing and in need of remedial action. This enabler activity was valuable to allow QL to proactively address network performance issues and deploy field-based engineering staff if necessary, to undertake remedial actions; refer to ***D7.5.***

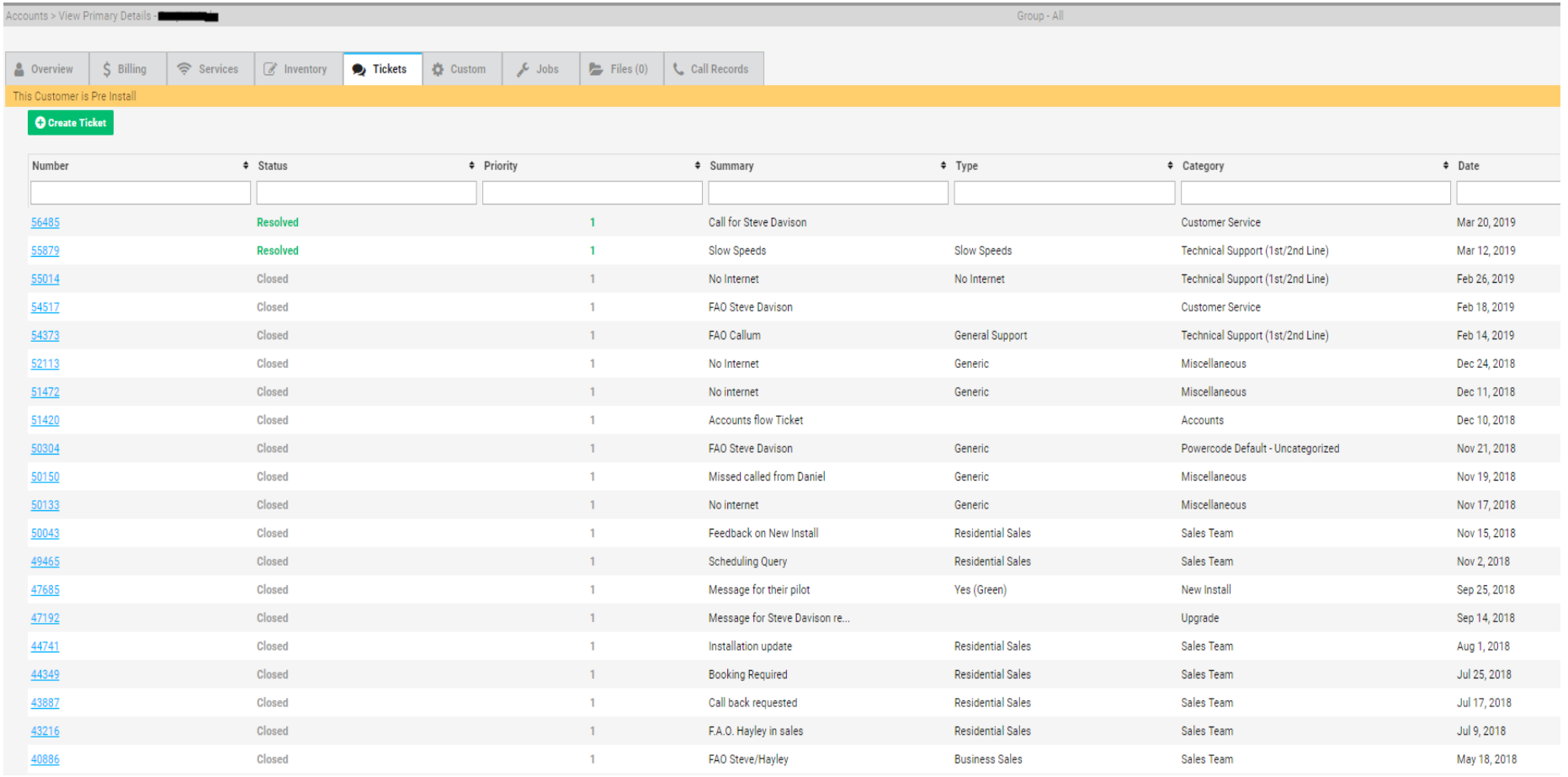
4.5. End User Feedback & Improvements

In regard to communication with end users participating in the trial, it is evident by their data submissions in previous report ***D4.6 First end user recruited, connected and initial trials completed***, that they have embraced the technologies deployed and have a genuine interest in future technologies. When issues have occurred, such as misalignment, QL has responded to maintain their service levels as though they were a commercial customer.

In the delivery of previous milestones, we requested speed tests and feedback from end users so they could tell their own individual user experiences as part of the respective use case. (For most cases this has been applied to teleworkers in respect of the 60 GHz deployment.)

As with all technology deployment, it was evident that the learning curve applied to all aspects of set-up and configuration, physical deployment to the end use case, and the ongoing support and maintenance of the service levels. Where necessary any lessons learned have been incorporated into the central spreadsheet.

Below see examples of support tickets raised by EU throughout TVWS trial at Longhills [for the purposes of GDPR the EU has been anonymised]:



Accounts > View Primary Details - [redacted] Group - All

Overview | Billing | Services | Inventory | Tickets | Custom | Jobs | Files (0) | Call Records

This Customer is Pre Install

Create Ticket

Number	Status	Priority	Summary	Type	Category	Date
56485	Resolved	1	Call for Steve Davison		Customer Service	Mar 20, 2019
55879	Resolved	1	Slow Speeds	Slow Speeds	Technical Support (1st/2nd Line)	Mar 12, 2019
55014	Closed	1	No Internet	No Internet	Technical Support (1st/2nd Line)	Feb 26, 2019
54517	Closed	1	FAO Steve Davison		Customer Service	Feb 18, 2019
54373	Closed	1	FAO Callum	General Support	Technical Support (1st/2nd Line)	Feb 14, 2019
52113	Closed	1	No Internet	Generic	Miscellaneous	Dec 24, 2018
51472	Closed	1	No internet	Generic	Miscellaneous	Dec 11, 2018
51420	Closed	1	Accounts flow Ticket		Accounts	Dec 10, 2018
50304	Closed	1	FAO Steve Davison	Generic	Powercode Default - Uncategorized	Nov 21, 2018
50150	Closed	1	Missed called from Daniel	Generic	Miscellaneous	Nov 19, 2018
50133	Closed	1	No internet	Generic	Miscellaneous	Nov 17, 2018
50043	Closed	1	Feedback on New Install	Residential Sales	Sales Team	Nov 15, 2018
49465	Closed	1	Scheduling Query	Residential Sales	Sales Team	Nov 2, 2018
47685	Closed	1	Message for their pilot	Yes (Green)	New Install	Sep 25, 2018
47192	Closed	1	Message for Steve Davison re...		Upgrade	Sep 14, 2018
44741	Closed	1	Installation update	Residential Sales	Sales Team	Aug 1, 2018
44349	Closed	1	Booking Required	Residential Sales	Sales Team	Jul 25, 2018
43887	Closed	1	Call back requested	Residential Sales	Sales Team	Jul 17, 2018
43216	Closed	1	F.A.O. Hayley in sales	Residential Sales	Sales Team	Jul 9, 2018
40886	Closed	1	FAO Steve/Hayley	Business Sales	Sales Team	May 18, 2018

4.5.1. QL Customer Results - TVWS

The below table highlights that across several EUs and given the combination of prevailing geography and terrain clutter, TVWS in this area was unable to deliver 30 Mbps broadband compliant services with BDUK's state aid requirements in a rural area.

Criteria	Customer 1	Customer 2	Customer 3	Customer 4	Customer 5
Equipment Deployed	6H TVWS	6H TVWS	6H TVWS	6H TVWS	6H TVWS
Deployed BS location (lat/lon)					
Deployed BS height	10M	10M	10M	10M	10M
Deployed receiver height	7M	7M	5M	5M	15M
Customer CPE location					
Services available prior to delivery of 5G network (download/upload speeds)	D: 2Mbps |U: 0.2 Mbps	D: 2Mbps |U: 0.2 Mbps	D: 2Mbps |U: 0.2 Mbps	D: 2Mbps |U: 0.2 Mbps	D: 2Mbps |U: 0.2 Mbps
Rates achieved (download/upload speeds), incl. stress testing (if available, e.g., iperf)	D: 12Mbps | U: 6Mbps	D: 10Mbps | U: 6Mbps	D: 10Mbps | U: 5Mbps	D: 8Mbps | U: 7Mbps	D: 15Mbps | U: 8Mbps

4.6. BP Customer Results – TVWS

See report D6.1 for technical information related to these links.

BP Has deployed 5 TVWS links so far on the Isle of Arran, Kintyre, Inverness-shire and Perthshire.

4.7. Isle of Arran

(Image removed)

4.7.1. General Feedback

We received positive feedback from the pilot customer at the point of installation and through a follow up consultation. The main feature the customer likes is the speed of the connection.

"We now get the fast broadband we could not get through the phone lines. We don't have to wait for things to download".

4.7.2. Faults

There is a new and outstanding fault on the system which requires Engineer intervention. The link has come loose due to the weight of the antenna mount on the chimney and has had to be temporarily relocated. We are in the process of working with the customer to redeploy the mount.

4.7.3. Success

The link achieved NGA throughput on a 16MHz channel.

4.7.4. Challenges

The antenna mount is too heavy for the deployment and we need to rethink the installation.

4.9. Kintyre

2 links deployed in Point to Multipoint configuration.

(Image removed)

4.9.1. General Feedback

Very positive feedback reported by owner of holiday properties.

“So far so good. The equipment has been in a few months now. Initially, we were sceptical, but it really does seem to work. We have enquired about more connections to replace our satellite links”.

4.9.2. Faults

There have been no faults reported or observed during the time the links have been operational.

4.9.3. Success

The link achieved NGA throughput to two holiday cottages in a point to multipoint configuration and have been extremely low maintenance.

4.9.4. Challenges

Engineers commented that the antenna assembly was difficult to install and that exposed position of the base station might be a problem in the future. So far, the assembly has been through two quite severe storms and it seems to be holding out.

4.10. Inverness-shire

Point to point link from POP to local business.

4.10.1. General Feedback

“Our new system appears to be working well so far. The front of the house picks up the 5G and the back of the house picks up the 2G. Had a little difficulty with signal during high winds, but we are on quite an exposed hilltop. I am sure when the smaller antenna is put in place of the larger one this will improve this problem a lot.

The people maintaining the Wi-Fi have been to the house on a number of occasions as seem very keen to try and get the system working at its optimum for us. The company also responded very quickly when I informed them about the wind interfering with the signal and

came along to improve the mounting. It is a much better system than the (generic mobile operator) box we had before, and it has made a difference to my daughters who use the system rather a lot. The real test will come when we have B&B Guests again next month. We are pleased with it overall so far."

4.10.2. Faults

We received 2 complaints about poor speeds and we are in the process of investigating an issue at the moment.

Following a storm, the antenna mount came loose and the mounting equipment had to be upgraded.

Following testing of the link we received notification from Lancaster University that the performance had degraded. We have a maintenance window schedule to investigate further. We believe this is an issues as a result of tweaking some of the settings to improve SNR.

4.10.3. Success

The link achieved incredible iPerf speeds on implementation. It is something of a miracle that the site is able to receive internet, let alone NGA broadband.

4.10.4. Challenges

None outside of expected implementation issues and aforementioned support issues.

4.11. Perthshire

Point to point link from POP to local business person.

4.11.1. General Feedback

Positive and detailed feedback.

"With the trees in the area not allowing a LOS service to be provided to the location via Broadway Partners, I was pleased to be considered for the TVWS trial in the area. The original location for the base station was tested with some earlier equipment, and whilst it worked it wasn't reliable. It was then decided to upgrade to the latest 5000 equipment and locate the base station on the hill at Nivingston Craggs but with shed/hill/trees in the viewing line – so not a good take off of signal. This also proved to be poor service reliability.

With the continued focus by Broadway Partners the base station was moved back to Classlochie and with support from the manufactured the service was tuned and is now delivering a reliable 10 x 5Mbps.

Whilst the antenna is large, in this installation this isn't an issue.

Resume – the principal of TVWS is very good, since between the base station and cottage we do not have LOS. However, the early days of the trial were certainly problematic, but with focus from Broadway this was overcome. Looking forward to onward reliable service."

4.11.2. Faults

There has been 1 reported fault since the relocation of equipment although this was an upstream issue and not a problem with the customer CPE.

4.11.3. Success

In a very difficult environment with limited channel availability we achieved USO download speeds.

4.11.4. Challenges

The initial 2 base station locations were different to the current Broadway POP site. We found the location to be problematic but at the time we didn't understand why.

We decided to move the connection to a closer POP. We got the link working at the new location on a single 8MHz channel.

When we were doing propagation model testing we found that that there was a lot of noise in the local area, especially for the client.

The noise increased with the bearing of the client towards the original installation location when we re-panned the antenna. We believe that the noise on the client end was the issue with the original installations.

A 16MHz channel is not possible due to noise at the moment.

There are no 24MHz channels available in either location to test.

4.12. Antenna Mount Issues

The biggest problem customers experienced during the pilot is the antenna mount. The large size of the aerials overloaded the standard mounts; to resolve this issue, we have had a bespoke mount designed by a new manufacturer which is a lot more robust. We have also designed aluminium cross section poles instead of steel to reduce the weight.

4.12.1. QL Customer Results - 60 GHz

The below table highlights that across several EUs and given the combination of prevailing geography and terrain clutter, 60 GHz in this area was able to deliver 30 Mbps broadband compliant services with BDUK's state aid requirements in a rural area.

	Customer 1	**Customer 2**	**Customer 3**	**Customer 4**	**Customer 5**	**Customer 6**
Equipment	IgniteNet ML22.6-60-35-UK	IgniteNet ML22.6-60-35-UK	IgniteNet ML22.6-60-35-UK	IgniteNet ML22.6-60-35-UK	IgniteNet ML22.6-60-35-UK	IgniteNet ML22.6-60-35-UK
Services prior to 5G connection	D: 30Mbps | U: 15Mbps	D: 30Mbps | U: 15Mbps	D: 30Mbps | U: 15Mbps	D: 30Mbps | U: 15Mbps	D: 30Mbps | U: 15Mbps	D: 30Mbps | U: 15Mbps
Base station location						
Base Station Height	14M	14M	14M	14M	14M	14M
Customer location						
Receiver Height	7M	7M	7M	7M	7M	7M
New Speeds	D 200 U 67	D 320 U 156	D 260 U 98	D 430 U 107	D 378 U 89	D 160 U 45

4.13. BP – 60 GHz Pilot

See work pack 6.1 for technical information related to these links.

The 60GHz pilot is behind the TVWS Deployment and will be finished by the end of March and over the next two months we will focus on collecting customer data.

Now that the equipment is in and settled full user testing can begin in full.

Upgraded Gigabit capable routers have been dispatched to site and the last Lancaster Consent forms have been received on the 26th March.

4.13.1. Initial General Feedback from Pilot Test Users

So far feedback has been positive, but the users have been testing in amongst a lot of technical implementation activity which some have noticed.

Trial 1 – Children have seen a significant improvement. They are now at an age where the local amenities are not of interest, being able to get online allows them access to their friends and online gaming services. In fact, a recent download game took about 5 minutes instead of two days.

Trial 2– The Trial Site has seen interest in utilising the internet services further. The new internet connection and speeds were a positive and constant point of discussion during the recent Rugby internationals. Upcoming events will be used to publicise the service and stress test the connection.

Trial 3 - Has only started to benefit from the extra bandwidth recently. There have been intermittent issues however, when they have been able to use the service then they have been able to utilise streaming services such as Netflix.

Trial 4 – The new speeds have meant that the Trial Site owner can now work from home and the children have better access for homework, intermittent drops in service (requiring a router reboot or reset) has been a cause of inconvenience.

5. NETWORK MONITORING

Both partners worked closely with Lancaster University who were responsible for the monitoring of the results (see report in WP 7).

Since QL's networks were built earlier there has been significantly more results for LU from the QL networks.

Broadway set out to install monitoring stations at each site supplied by Lancaster University. There has been a delay in deployment due to an ethics committee issue the University project team dealt with. Broadway are still in the process of deploying the monitoring equipment.

Now that the equipment is installed, deployed and working for both the TVWS and 60GHz pilot we will continue our work with Lancaster and gather more detailed user feedback. We expect to achieve NGA speeds on the TVWS links and prove the reliability of the mesh technology in rural for the 60GHz equipment.

6. KEY LEARNING POINTS

6.1. Quickline

The following summary points of the trial were key QL learnings:

6.1.1. Selection of technology and supplier

- The choice of TVWS supplier had a significant impact on the project's deliverables from a QL perspective, and it could also be suggested this further extended to other consortium members who had responsibility to implement in their chosen geographical areas. Given the relative technology immaturity, by comparison to commercially established equipment, QL has found diagnostics and equipment set-up challenging.
- In regard to the TVWS equipment supplier, and the relative immaturity of the technology, QL encountered a significant delay in supply of equipment. This meant that between order placement and gaining active experience in its deployment, there were periods of inactivity throughout each implementation milestone which allowed QL to focus its attention in favour of 60 GHz equipment and look for alternative technologies to implement in alternative test bed areas.
- Once next generation equipment becomes available QL will consider its deployment to replace the existing to determine any generational improvements regarding deployment, set-up and management.

6.1.2. Alignment

- With any line of sight (LOS) and non line of sight (NLOS) technologies, alignment between base station and customer end point is key to ensure service provision. Weather plays a major role in maintaining alignment and given the prevailing times of year QL has learned that wind and rain are significant contributors to performance.

6.1.3. Use cases and end user adoption

- Inability of the hardware to cope with the particular circumstances of rural farming areas, mitigated by ensuring systems are tested thoroughly in the field before end users test them.
- Stigma of equipment installation; given the large footprint of TVWS equipment it was not looked upon favourably to begin with and attracted negative criticism from the installation test bed. Equally, there exists at present a significant amount of negative press surrounding 5G technologies. The 5GRIT consortium has always sought and been provided with assurances from DCMS to refer any issues to Public Health England. As well as this, 5GRIT members attended a public meeting held in Alston in March to respond to questions posed by the general public and provide assurances of why and how the technologies were to be deployed. Reassurances from PHE and attending the town hall meeting managed to mitigate some of the public concerns.

6.1.4. Management of end user expectations

- Throughout each deployment test bed, for both TVWS and 60 GHz equipment, QL has actively managed the expectations of end users. An example of which is that the TRL of the equipment was made known, and as such it will be prone to service issues and possible service drops from time to time, particularly during bad weather as was noted with the 60 GHz equipment.

6.1.5. Managerial

- Contracts - Public land owners and organisations not willing or able to respond accurately or in a timely way, which led to the slow down of project momentum in particular for the UAS use case. An example of which is when trying to implement infil mast sites, QL has completed site surveys and issued license documentation for potential mast holders to accept, without which we are unable to proceed. QL has experienced significant delays in moving such elements forward.
- Lack of adoption for using 5G applications - the concern being potentially not enough end users to undertake service testing and so produce a set of results which may not be representative of the input efforts; this challenge sits across all use cases.

6.1.6. Environmental

- Adverse weather [high wind, rain], has been a major contributory factor in delays to deployments and site surveys, which has led to rebooking of appointments and equipment necessary to complete the remedial actions.

6.1.7. Safety

- Safety concerns expressed over ‘new technology’ from public; usually this can be mitigated by attending community / parish council meetings where necessary to field questions from the floor, and a concerned public. Between Cybermoor and QL we have attended several public meetings with a view to responding to questions submitted from the public to appease any anxieties raised from unofficial sources.

6.2. Broadway Partners – Research Questions & Answers

The key learning points from BP’s work is set out in detail in the WP6 report.

6.2.1. TVWS

Two Key Questions were posed:

- Question 1

  Are current propagation models utilised in dynamic spectrum regulatory framework transferable to WSD planning and deployment?

- Question 2

Has TV White Space come of age? Can White Space technology be utilised now to deliver applications such as broadband and achieve modern performance standards?

Answers, in summary:

- Question 1

  No, it would appear that Hata Extended with the suburban / urban clutter assumption does not transfer to good results when planning TVWS links. The best propagation model we found was Longley Rice with a Terrain 50 dataset.

- Question 2

  USO universally achievable in testing. TVWS is a good technology in a lot of areas for NGA speeds with 70Mbps achieved during testing.

6.2.2. Questions – 60 GHz

As above, two key questions were posed:

- Question 1

  Should 60GHz technology be considered at all for rural deployments?

- Question 2

  Does new point to multipoint / mesh technology offer any benefits in a rural environment?

Answers in summary;

- Question 1 - 60 GHz has a pivotal and complementary role in rural environments.
- Question 2 - Yes, there are NLOS and deployment benefits to 60GHz mesh.

7. SECURITY REVIEW

Quickline are an established Telco and as such will have some accreditations to adhere to, such as ISO 9001, 27001 and 45001 which will have elements of security involved in addition they will deal with regulations set by Ofcom.

Personnel awareness is something that QL are aware of and staff are subject to onboarding processes including vetting (standard and means TBC).

Purchasing of equipment is carried out through established and reputable companies.

Detailed security review

8. RESULTS, FUTURE WORK & CONCLUSIONS

The findings revealed from phase 1 differ between technology deployments.

In respect of TVWS technology deployment, QL will declare that at the current TRL, it has had mixed results. While the base station implementation between Mount Hooley (Alston, Cumbria) and the customer premises at Nenthead Mines and the Youth Hostel (to assist and support the tourism [AONB, WAM] and farming [Precision Decisions] applications) have brought some successes to the project, the same cannot be said to be true in Longhills, Lincolnshire, deployed to support the rural broadband implementation.

A number of factors have led to these differences, significant among which are the combinations of terrain clutter, and available TVWS contiguous channel spectrum for each selected area. For example, in the Longhills area the available spectrum channels suggest that QL should have been able to bond three or more channels together and so attain superfast speeds to support the teleworker use case [***See D4.1 Personas and Use Case Report180510***] . The reality of this does not always reflect the desk based analysis pre-work as, when the third channel is bound, the entire service drops back to single digit connection, regardless of the combination of three channels used from the available spectrum.

Scaling this technology up into a phase 2 proposal clearly has significant challenges, particularly the combination of TRL, ground clutter and channel spectrum availability. One suggestion is to look to alternative TVWS technology providers and determine a comparison of capabilities which may provide more favourable results.

The conclusion at this stage for TVWS is that in order to progress this technology, QL requires a higher TRL in order to revisit the phase 1 trials, before any consideration can be given to progressing to phase 2 higher density deployment. Having consulted suppliers, QL believes that the higher TRL may become evident towards Autumn 2019; on its release QL may re-engage with the hardware vendors and also consider alternatives.

In respect of 60 GHz equipment, QL has experienced more consistent and positive results regarding the TRL. Whilst we have tested individual point to point links and single access points running a smaller number of connections, we have not yet been able to test multiple transmitters in a small geographical highly dense area all running simultaneously.

QL's trial users have consistently reported high double digit speeds tests as revealed through the implementation and milestone reporting - see ***D4.8 Report on success in recruiting end users and delivering the 5G service, and user feedback from the first round of trials***.

Building up to phase 2, we see 60GHz density as a key item to test. The aim would be to obtain further insight into propagation, into link performance, and into whether there are interference issues when the grid becomes more dense.

To measure interference, we will monitor the signal to noise ratio of the clients to AP connections. Furthermore QL plans to monitor the sustained modulation levels of clients as more connections are activated, by running iPerf tests from the core network to end users to monitor true link performance (across the link) as the density of the network increases.

The proposal and conclusion at this stage for 60 GHz equipment is to progress this technology into phase 2 testbed development, wherein it will coexist with established and commercial technologies to evaluate link alignment, performance and delivery of applications across the user cases studies in a rural environment.