WPD INNOVATION
Transforming the electricity network

LTE Connecting Futures Project

Closedown Report

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1. Executive Summary

1.1. Introduction

The 'LTE Connecting Futures' Network Innovation Allowance (NIA) project has successfully completed the work detailed within the project scope document. The project has demonstrated how grid assets could be administered by using Long Term Evolution (LTE) technology, how such a system might be designed and integrated, the technologies and technology roadmap which might be adopted, and the enabling steps that would need to be undertaken or considered in the short to medium term. Despite the project requiring a six month extension due to the impacts of COVID-19, all of the expected project outcomes were successfully delivered.

Utility networks, and particularly electricity networks, are in a period of significant transformational change as a result of decarbonisation, decentralisation and digitisation. The telecommunication solutions necessary to support the future critical, national infrastructure will need to be much more advanced than those used in the past. Therefore, it is likely that the telecommunications of energy networks will need to be completely re-engineered in a short timescale to support the rapid changes ongoing within the industry. Moreover, and increasing the complexity and urgency of this challenge, the telecommunications landscape itself is rapidly changing, with developments ongoing across regulatory, technological, and commercial sectors.

Therefore, the development of a smarter electricity grid is necessary to meet the UK government's commitments, including the establishment of a modernised and secure telecommunications infrastructure. Existing telecommunications systems were developed in the 1950s, when power systems were based on a 'top-down' model, and required minimal management. Today's systems are much more complex, and although the technology deployed in electricity management systems has evolved to be more scalable, there is an imminent need to drastically modernise the entire telecommunications system in order to meet ever-important emissions targets.

For a number of years, WPD have been working with partners to gain a more detailed understanding of the best method for modernising our telecommunications network. Over this period it has become increasingly apparent that a dedicated 'utility' telecommunications network will need to be established in order to provide the functionality, security, reliability, resilience, and geographical reach required by Distribution Network Operators (DNOs).

The 'LTE Connecting Futures' NIA project was centred on the use of LTE technology developed by the 3rd Generation Partnership Project (AC)
as a broadband data network standard. The LTE technology developed by 3GPP utilises 3MHz of Ultra High Frequency (UHF), providing an Internet Protocol (IP) native platform capable of supporting critical monitoring and control applications. Hence, it has already been accepted and adopted by a number of countries.

There are key technological, security, and financial advantages associated with LTE compared to alternative technologies. For example, the technology is mature and well proven in both public and private scenarios, and standardisation of the technology facilitates multi-vendor support, reducing the overall cost of ownership and offering a better return on investment.

The 'LTE Connecting Futures' success has given the United Kingdom (UK) the potential to catch up with leading international utilities. Further plans are already in place to continue to use the platform established by the project, both physical and intellectual, to progress with the development required to be able to commence roll-out of the solution when necessary.

It has been identified that the remaining obstacles to a dedicated utility network in the UK are more strategic than technical, and are mainly governmental: regulatory policy, funding and procurement strategies. While this report makes no comment or recommendation with regard to governmental policy and strategy, it is intended that it will provide useful information in enabling the next steps for overcoming those obstacles.

There is already a strong multi-vendor market in place for LTE, and although the 'LTE Connecting Futures' NIA project has already tested a number of devices, communications will continue to rapidly develop, enabling wider choice of applications and vendor equipment, which WPD will continue to monitor and evaluate.

2. Project Background

The ‘LTE Connecting Futures’ NIA project was the UK’s first multi-site, multi-vendor LTE trial; designed to emulate a small scale telecommunication system, and to develop proposals for the deployment of a telecommunications network to support Active Management and Smart Grid functionality. The project built upon knowledge gained from the ‘Portishead LTE trial’ (Phase One) and ‘Next Generation Telecoms Analysis’ (Phase Two).

The Portishead LTE trial provided data on the fundamental design and capabilities of LTE, and illustrated how such a communications network might be integrated into our infrastructure. In addition, the project confirmed that an LTE network was better equipped than a traditional Supervisory Control and Data Acquisition (SCADA) network to deliver the required data throughput, in consideration of the environments typically associated with utility assets e.g. electrically noisy sites, Radio Frequency Interference (RFI), and multipath propagation.

The Next Generation Wireless Telecoms analysis followed on from the Portishead LTE trial, and was completed in collaboration with the Joint Radio Company Limited (JRC). The analysis established a provisional model of network planning methodology and technical infrastructure for an LTE radio network deployment across single or multiple Distribution Network Operator (DNO) area(s). It was crucial that the ‘Next Generation Wireless Telecoms’ project established the scalability of the deployment of LTE, particularly because traditional narrow-band SCADA systems do not have the ability to support the required number of connections and services across future utility networks. Therefore, by developing a plan for the deployment of an LTE radio network, the ‘Next Generation Wireless Telecoms’ project was an important step in reducing the risks associated with achieving the predicted coverage and capacity in any subsequent full-scale rollout.

The ‘LTE Connecting Futures’ NIA project utilised an LTE network to provide connectivity to a range of energy network assets. Working with suppliers such as Nokia, three LTE base stations in adjacent locations were installed and connected back to a central Evolved Packet Core (EPC), emphasising the minimal construction requirements of a basic LTE network, and providing WPD with the ability to evaluate the characteristics of LTE.

3. Scope and Objectives

The project had a number of key objectives that it sought to achieve as part of the project lifecycle, as detailed within the Project Scope. These were impacted by the COVID-19 pandemic, but were met once the project extension had been approved.

Table 1: Status of project objectives

Objective	Status
Determination that LTE could be a suitable solution for providing future communications for the energy industry	✓
Determination of the minimum bandwidth requirements necessary for a utility LTE network	✓
Determination on different data types that can be transported over an LTE network	✓
Determination on antenna solutions for different situations	✓
Determination on training needs, skill sets and test equipment requirements	✓

4. Success Criteria

The project had a series of Success Criteria, agreed with the business, which it sought to achieve as part of the project lifecycle, as detailed within the Project Scope. Although the success criteria were impacted by the COVID-19 pandemic, most were met once the project extension had been approved. However, it was determined that LTE could not support low-latency applications.

Table 2: Status of project success criteria

Success Criteria	Status
Confirmed propagation predictions and performance in a multi-site environment	✓
Confirmed seamless interoperability of multi-vendor CPE and EPC equipment	✓
Security & authentication successfully tested on LTE ecosystem	✓
Testing of mobile and handheld device connectivity including Wi-Fi	✓
Confirmation that LTE will support low-latency applications such as tele-protection	× Latency was proven to be too high to transport tele-protection services over LTE
Document(s) outlining installation practises, test regimes and training requirements for LTE	✓

5. Details of the Work Carried Out

5.1. Introduction

The work was carried out by a joint project team, comprising technical & project management professionals from the three partner organisations, namely WPD, Nokia & JRCL.

The 'LTE Connecting Futures' NIA project focussed on the technical feasibility and performance of a multi-vendor, private LTE utility services network.

The use of LTE enabled a rich multi service broadband IP platform to be proven in the Taunton Lab and field substation environments. This supported SCADA, and the testing of IEC 60870-5-104[1] and DNP3[2], with the intention to test IEC 60870-5-101[3] using serial communications to the remote grid devices.

5.2. Lab & Field Environments

Development and testing of the LTE network was undertaken in two environments. Initially, the system was built and commissioned in a controlled environment at the Taunton lab, providing baseline values on system performance and testing. Later on, the field network was used, which included a total of three Base Stations and 10 Customer Premises Equipment (CPE) locations, enabling testing of realistic operational scenarios in a substantial substation environment. This allowed the project team to determine how scenarios that mimicked real-life affected performance of the LTE network when compared to the baseline values obtained in the controlled laboratory environment.

Although work in the lab environment continued for the duration of the project, field testing was only carried out once the field network became available. Over the lifecycle of the project, lab work became increasingly focused on the core network, and core applications such as Group Communications and management. Conversely, the field work maintained primarily focused on the radio network dynamics.

The approach described enabled the Project Team to:

- gain familiarisation with the system architecture and operation;
- learn how to validate, operate, and troubleshoot the components;
- optimise field time to eliminate unnecessary trips to the field; and
- create a performance baseline by which to compare field testing performance.

The list of tests conducted within the lab and field environments are shown in Table 3:

Table 3: Tests Conducted in the Lab and Field Environments

Test Conducted	Lab	Field
Hardware Failover & Recovery	X	X
Throughput performance End to End (E2E)	X	X
RAN / RF Signal Quality and Performance Benchmarking	X	
RAN / RF Coverage Testing		X
Security and Penetration Testing	X	
Multi-tenancy Resource allocation and privacy	X	X
Throughput performance with QoS	X	X
Mobile Voice (MCPTT)	X	X
Mobile Video (MCPTV)	X	X

[1] Extension of IEC 101 protocol.
[2] Distributed Network Protocol 3 is a set of communications protocols used between components in automation systems.
[3] A standard for power system monitoring, control & associated communications.

Fixed Voice for substations (VOIP)	X	X
CCTV Review	X	X
Wi-Fi & Mobile Data	X	

5.3. RF (Radio Frequency) Coverage, Signal Quality & Data Throughput Testing

Bench testing was carried out in the lab to:

- Verify the radio frequency parameters and resulting performance of system; and
- Check the precision of signal quality metrics to understand the performance of the network.

The results from the laboratory testing can be provided upon request.

5.4. Field Environment

The purpose of field testing was to determine the End to End ('E2E') performance of the LTE system in real world scenarios. The resulting performance data, specifically in testing operational SCADA protocols, can then be used in the future to determine best practices, design criteria, and recommendations or limitations on radio performance.

The results from the field testing can be provided upon request.

6. Performance Compared to Original Aims, Objectives and Success Criteria

The project has met the following with regards to the project aims, objectives, and success criteria:

Objective/Criteria	Status	Performance
Confirmation of the propagation predictions and performance in a multi-site environment	✓	The ability to measure the signal contribution from each sector (eNodeB), using the 'Rohde & Schwarz TSMA Autonomous Mobile Network scanner', allowed the mobile measurements to be compared with predictions. The distribution of measured vs predicted signal levels for each sector (eNodeB) matched expectations. This allowed the correct RF performance of the installed network to be confirmed. This objective is complete, and concludes that the actual received signal levels closely align with the respective received signal level predictions generated.
Confirmation of the seamless interoperability of multi-vendor CPE and EPC equipment	✓	The project was successful in integrating Encore EN2000, EN4000 and EN4000ie's to the Nokia Evolved Packet Core (EPC) and successfully established both clear channel and Internet Protocol security (IPSEC) tunnel connections across the network, from the gateway local area networks (LANs) to the CPE LAN. The Encore Networks EN4000 series is a high performance low–cost router designed for LTE cellular networks. The project was also successful in integrating Nokia service aggregation router (SAR-Hmc) CPE's to the Nokia EPC utilising IPSEC tunnelling. This objective is complete, and concludes that multi-vendor CPE's can seamlessly integrate with existing RAN and core components.
Security & authentication successfully tested on LTE ecosystem	✓	The PEN tests took place in February 2020 and April 2021, and identified a number of vulnerabilities in the LTE platform. Both Nokia and Encore networks developed firmware updates for the CPE's, the eNodeB's, and the EPC and these were implemented. The EPC, which comprised of Nokia's Micro Core Network (MCN), was a legacy product and it was replaced with Nokia's latest generation – the Compact Mobility Unit (CMU). This objective is complete, and the recommendations from these tests are in the process of being fully implemented.
Testing of mobile and handheld device connectivity, including Wi-Fi	✓	The project successfully connected Mission Critical Push to Talk (MCPTT), and fixed telephony Voice, over IP (VOIP) equipment across the LTE network. Inter-system test calls, including mobile voice and mobile video connectivity via Wi-Fi connections to the CPE, were also established. This objective is complete, and concludes that the LTE platform can successfully integrate both MCPTT and VOIP voice and video services.
Confirmation that LTE will support low-latency applications such as tele-protection	*x*	DIP5000 Tele-Protection relays were installed within the lab environment. However, due to the unavailability of the C37.94 over IP multiplex equipment, it was unfeasible to connect the relays together over the LTE platform. The equipment had not been

		released from Customs in time for completion of the project. Therefore, this objective was not completed in time for the project end date. However, latency testing identified that LTE, in its current configuration, would not be able to meet the required minimum latency to successfully transport Tele-Protection services.
Document(s) outlining installation practises, test regimes and training requirements for LTE	✓	Nokia provided digital copies of the standard Nokia installation documentation, as well as the High Level Designs (HLD) outlining the specifications of the solution. Test plans provided step by step instructions on test procedure, in addition to associated commands, and were delivered for the various project work packages. WPD were provided with both hands on training, and logins for formal Nokia 'on-line' modular training. This objective is complete: WPD received formal online module training, hands-on training, specialised one-on-one training and delivery of technical manuals for reference.
Confirmation that LTE is a suitable solution for providing communications for the energy industry	✓	LTE is an IP based carrier platform and as such allows for the connectivity of a diverse range of services. Existing utility spectrum is 'service' based, and as such cannot 'share' resources, whereas LTE is a shared resource. The project successfully carried voice, data, and video from a number of substations back to the central test lab, connected to various application servers. Testing and analysis was carried out to evaluate traffic flows and resource usage, including the implementation of traffic shaping techniques such as Quality of Service (QOS) and priority queueing. This objective is complete.
Confirmation regarding using a Frequency Division Duplex (FDD) or Time Division Duplex (TDD) system	✓	The Nokia LTE system deployed FDD as its mode of operandi in Band 87 (410-430 MHz), which separated the Downlink and Uplink segments into distinct frequency bands. The choice of using either FDD or TDD was determined by the frequency band for which the LTE system was deployed. This objective is complete, and concludes that FDD can be deployed locally, regionally or nationally within the UHF spectrum.
Confirmation on bandwidth requirements	✓	Our LTE system was configured to operate in a 2 x 3 MHz FDD channel. Evaluation of channel usage has been completed, and provided evidence of the bandwidth requirements. This objective is complete, and concludes that 2 x 3MHz is an absolute minimum bandwidth necessary to carry WPDs anticipated services over LTE.
Confirmation on types of data that can be passed over an LTE system	✓	The project successfully connected H.264 compressed video, SIP's and VOIP telephony, MCPTT voice, DNP3 and IEC870-5-104 SCADA data, Simple Network Management Protocol (SNMP), Transmission Control Protocol (TCP) and User Datagram Protocol (UDP) data streams, Hypertext Transfer Protocol (HTTP) and Hypertext Transfer Protocol Secure (HTTPS), and File Transfer Protocol /Secure File Transfer Protocol (FTP/SFTP) file transfers. Hence, this objective is complete

Confirmation on antenna solutions for different situations	✓	The project involved the installation of two versions of omni-directional antenna to a number of substation locations, which allowed for the assessment of 'best practice' installation techniques. Therefore, this objective is complete.
Confirmation on training requirements and test equipment for staff	✓	Nokia had provided access to an LTE training programme where WPD staff were able to work through various aspects of the LTE eco-system at their own pace. On site and remote training had been carried out during active system configurations. An assessment of RF Drive test equipment from a single supplier had been beneficial in providing training requirements and technical evaluation of LTE test equipment. WPD had received datasheets, documentation manuals, and interaction with a number of vendors for evaluation which will be used to develop a 'shopping list' for any future test equipment procurement. This objective is complete.

7. Required Modifications to the Planned Approach during the Course of the Project

Due to the ongoing effects of the coronavirus pandemic, various project activities were postponed and delayed, and hence the LTE Connecting Futures project was awarded a 6 month extension.

8. Project Costs

Table 8: Project Spend

Activity	Budget (£)	Actual (£)	Variance (%)
WPD Internal Costs	336,958	353,311	~ + 5
LTE – All Contractors	810,000	641,151	~ - 21
Total	1,146,958	994,462	~ - 13

Due to labour requirements generated by the project extension, there was a 5% increase on the internal costs. The number of personnel needed to complete the planned installations had to be increased. Had this action not been taken, the completion deadline for various milestones, and hence the entire project, could have been missed.

The contractors' costs were lower than anticipated due to efficiencies that could be made.

9. Lessons Learnt for Future Projects

Lessons learnt for future projects are outlined below and include:

- **Network Management**

Through the project, we were able to provision end to end services. However, no network management platform was instigated at the outset of the project which made it difficult to implement IP/MPLS and QoS services across all devices. Whilst these service areas were possible, they were significantly more challenging to implement.

Operations, Administration and Maintenance (OAM) network management tools, and IP/MPLS services are deemed essential for large scale deployment.

- **Spectrum Availability**

We were able to secure radio spectrum for the trial under OFCOM's Test & Development license terms and conditions. LTE spectrum is governed by international agreements, as defined in the 3GPP (3rd Generation Partnership Project) suite of standards. In order to engage with Radio Access Network (RAN) vendors, spectrum licenses must be deployed in one of the 3GPP frequency bands. This frequency band must also be available in the region of deployment whilst also meeting the conditions as determined by OFCOM. Spectrum availability is challenging within the UK, and the project team had been fortunate enough in obtaining Test and Development licenses. These licenses had to be applied for on an annual basis and there was no guarantee that the project would be successful in procuring future licenses.

The procurement of radio spectrum for the LTE trial highlights the difficulties in obtaining spectrum for private LTE. It is paramount that the utilities, peer groups, lobbyists, regulatory bodies, and vested parties are united in procuring radio spectrum to meet the net zero carbon objectives of the utilities and the UK.

- **Security Vulnerabilities**

We were able to perform PEN testing on the LTE system, which comprised a mixture of hardware and software components, with an increasing dependence on the software element. This emphasised the extreme importance in evaluating any security vulnerabilities which the software may inherently contain. The discovery of vulnerabilities in the software can have a detrimental effect on the project outcomes. Penetration or PEN testing is the de facto method for evaluating software before it is deployed into any system, and should be carried out as early in the project lifecycle as possible.

- **IP Planning**

Nokia were instrumental in planning the IP network for the LTE RAN and core network, which also required strategic understanding of our IP network. Nokia were provided with a suite of IP addresses in which to build the LTE platform, which included the list of router connectivity for binding the system together.

Networks are increasingly deploying IP based solutions and whilst this simplifies the physical connectivity, it increases the complexity of network configurations. In a multi-vendor environment, understanding the co-existence and integration of the various components of the system should be planned at the early stage of the project. Its also necessary to recognise that LTE equipment can be sourced from multiple vendors, and IP planning is fundamental in accommodating the different configurations required for each application.

A single vendor solution simplifies the IP planning and system configuration. However, there is a risk that the scope of the project becomes biased to a solution favoured by a particular vendor.

A key learning which developed from this project was the importance of a detailed understanding of the needs of both the system being implemented, and what our Data Core Network (DCN) actually supported. A typical example was Nokia's efforts in deploying an IP/MPLS topology, where we had to change the system to meet the needs of what we can currently support, which was not IP/MPLS based.

We were also able to produce an overview of an IP addressing scheme to facilitate a future 'live' LTE deployment that avoids ambiguity in system configuration and promotes healthy network planning.

- **Remote Access**

Consideration should be given to deploy remote access for support teams at the outset of any project.The response to remote access for this project was reactive in the light of COVID-19, but the learning is that this has a significant advantage to the project, especially whilst the system is being developed, and where there are specific issues which require 'expertise' to rectify. Planning for future projects should include full contingency for remote access for management and configuration.

- **RAN Installation**

The hybrid cable development may not necessarily be the optimal solution when installing RAN base stations (eNodeB's). Separate fibre and DC cables may be a simpler and more cost-effective solution. We will be reviewing the installation of the hybrid cables with our installation team as part of the learning process.

- **400 MHz Frequency Band**

The radio equipment in this project was able to operate in the 400 MHz (UHF) frequency range. This spectrum band is commonly termed the 'Sweet-Spot' for critical telecommunications and is always in great demand for critical applications due to its capability to provide good coverage, and capacity with a reasonable data payload and relatively compact antenna sizes.

- **Bench RF Measurements**

Within bench measurements, the possibility of signal leakage and equipment cross coupling should be considered, and the impact on testing fully understood. Separating equipment and using screened enclosures offers mitigation. Carefully calibrated, conducted paths are more preferable than radiated paths.

- **Field RF Measurements**

The use of a dedicated test receiver that was able to identify and report parameters individually from each eNodeB, was essential in checking and understanding RF performance.

- **Connectivity**

LTE provides the transport medium for data and voice services such as SCADA, mobile data, mobile voice, mobile video, fixed voice and Closed Circuit Television (CCTV) etc. This trial has been able to assess the capability of LTE to connect these services to our network.

- **LTE Core Replacement**

As a result of Penetration Testing, Nokia replaced the Micro-core Network (MCN) variant of the LTE Core with their current release called Compact Mobility Unit (CMU+), which included the latest patches and firmware. The original MCN Core was a legacy Nokia product. The CMU+ was intended to mitigate the findings in the PEN tests.

- **License Management**

We were able to maintain a register of software and spectrum license expiration dates in order to prevent system downtime due to inadvertent system shutdowns. Shutdowns are difficult to fix in emergency situations, and can incur significant delays in restoration due to the requirement to conduct diagnosis and rectification processes.

- **Band 87 handsets**

We were able to migrate all existing Band 126 CPE’s to the 3GPP standardised Band 87.

- **Training**

Nokia had provided access to an LTE training programme where our staff were able to work through the various aspects of the LTE system at their own pace. On site and remote training had also been carried out during active system configurations.

It became clear during the course of the project that ‘Hands on’ training was the most effective form.

As this was a relatively new technology to us, there was a large element of learning and discovery. Nokia was also subjected to an element of learning, especially after the deployment of the new EPC, as some aspects of the deployment was also new to the key personnel assigned to the project. This created a lag in the teams’ ability to progress with the project quickly, but did not subsequently have a significant impact on the overall project.

Whilst this is an excellent way to fully understand a system, it slows the progress to a degree. It might have been preferable for an ‘overview’ training course to be conducted early in the project to gain a basic understanding of the system, supported by the ‘hands on’ training which followed.

10. The Outcomes of the Project

Some of the outcomes on the project include the following:

- **Creation of a Multi-Base Station Network**

The key outcome of the project was the creation of a multi-vendor multi-base station LTE configuration, consisting of a three sector (cell) base station at Taunton and two single sector (cell) base stations at Elworthy Burrows and Bowdens Hill respectively. This was an important follow up to the single vendor, single base station LTE evaluation trial at Portishead, which mainly provided data on the fundamental design and capabilities of LTE and illustrated how such a communications network might be integrated into our infrastructure. No energy utility or sector service provider had carried out a multi-site, multi-vendor LTE trial with adjacent eNodeB's in a 'real' energy environment. This project has demonstrated that a multi-base, multi-vendor network could be realised.

- **Radio Frequency Field & Drive Test Measurements Report**

A report on Field Testing and Drive Tests has been produced. Field testing, within the geographic service areas of the three Base Stations, was designed to achieve the following:

- Verify the accuracy of radio frequency coverage predictions;
- Provide guidance in the location of test CPE sites;
- Provide a reference source when examining the selection of best serving base station by each CPE site; and
- Measure radio frequency noise levels, adjacent to CPE sites.

- **Penetration Test Report**

A report on PEN Testing has been produced. This report covers the recommendations on the improvements to the operability and integration of the various LTE components.

- **High Level Design (HLD) document**

A document detailing the structure and the assembly of the LTE configuration has been produced for the project. The document outlines the standard Nokia installation and specifications of the LTE solution.

- **Training Materials**

Online training materials have been developed for our staff. These are accessible using an approved passcode.

- **CIRED Conference 2021**

A technical paper on this project has been written and accepted for presentation at the CIRED conference in September 2021.

11. Data Access Details

The close down report will be available on WPD's website. Any data produced during the course of the project will be available to share in accordance with WPD's data sharing policy:

www.westernpower.co.uk/Innovation/Contact-us-and-more/Project-Data.aspx

12. Foreground IPR

No IPR was created for the project.

13. Planned Implementation

This project provided us with learning and experience in designing and delivering LTE networks and this will be used in our future BaU development of our telecoms network. We are confident in our ability to deliver a private LTE network linking our primary and distribution substation sites. We own and operate the largest telecommunications network amongst all of the DNOs. Through this experience, we have gained deep institutional capabilities in the deployment and operations of telecommunications assets. Accordingly, we view the deliverability of these works as low risk when considering all of the factors under our control. However, as we are dependent on Ofcom awarding adequate spectrum to support us with the delivery of a smart, flexible energy system, the overall deliverability risk of these works is high.

14. Contact

Further details on this project can be made available from the following points of contact:

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Glossary

Abbreviation	Terminology
3GPP	3rd Generation Partnership Project
AC	Alternating Current
CCTV	Closed Circuit Television
CMU	Compact Mobility Unit
CPE	Customer Premises Equipment
DCN	Data Communication Network
DNO	Distribution Network Operator
EFE2E	End to End
eNodeB	Evolved Node B Base Station
EPC	Evolved packet Core
FDD	Frequency Division Duplex
FTP	File Transfer Protocol
GPS	Global Positioning System
HLD	High Level Design
IEC	International Electrotechnical Commission
IP	Internet Protocol
IPSEC	Internet Protocol Security
JRCL	Joint Radio Company Limited
LTE	Long Term Evolution
MCN	Micro Core Network
MCPTT	Mission Critical Push To Talk
MCPTV	Mission Critical Push To Video
NIA	Network Innovation Allowance
OAM	Operation, Administration and Maintenance
OFCOM	Office of Communications
PTT	Push-to-Talk
QoS	Quality of Service
RAN	Radio Access Network
RF	Radio Frequency
RFI	Radio Frequency Interference
RTU	Remote Telemetry Unit
SAR	Service Aggregation Router
SCADA	Supervisory Control and Data Acquisition
SFTP	Secure File Transfer Protocol
SNMP	Simple Network Management Protocol
TCP	Transmission Control Protocol
TDD	Time Division Duplex
UDP	User Datagram Protocol
UHF	Ultra High Frequency

VOIP	Voice over IP
Wi-Fi	Wireless Fidelity