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Remote and Rural Resilience for EV Infrastructure

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Prepared By:	Kinan Ghanem, Stephen Ugwuanyi
Reviewed By:	Stephen Ugwuanyi, Kinan Ghanem
Authorised By	Federico Coffelle
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EXECUTIVE SUMMARY

Reliable and secure communication technology is one of the key requirements to ensure the flow of EV charging services for reasons like digital transition in pursuit of net zero targets. A wide range of communications technologies can be used to enable the connectivity needed to monitor the EV charging stations. In the hard-to-reach areas, the suitability of Low Power Wide Area Networks (LPWAN) technologies such as NB-IoT, LoRa and RPMA, and BGAN satellite communication along with G4/G5 and private LTE vary based on their availability, the main end applications and the associated costs.

PNDC has been approached by HITRANS to look at the key challenges and solutions that face the availability of communication technologies and the impact of switching off the 3G network in the. In this report, PNDC has identified the key challenges of EV infrastructure in remote and rural areas along with the appropriate solutions and the cost associated of each recommended option.

This project has explored the key technologies that can be deployed in hard to hard-to-reach remote and rural areas, taking into considerations their main advantages, disadvantages and estimated costs for EV charging infrastructure. The report identifies potential future technologies that could be used or easily Moray, Western and Northern Scottish Isles including Shetland and Orkney deployed to meet the communications and cyber security requirements for EV charging in the Scottish Isles. The report also focuses on the communication requirements for the EV charging infrastructure and covers the available communication technology options that are most suited for this application – highlighting the advantages and limitations of each option.

The report includes Learning from previous relevant innovation projects and previous experience we have built over the previous years and it answers the following questions:

- What are the recommended communication technology options to be used in connecting the EV charging stations in the hard-to-reach areas?
- What are the key requirements to enable the functionality of the EV charging by reliable and secure communications?
- What is the impact of switching off the 3G network in remote and rural areas of Scotland?
- What are the short/long terms communication solutions to be considered in the EV charging?

During this project, t has been found that the right connectivity for EV infrastructure in the highland namely some areas in Moray, Western and Northern Scottish isles including Shetland and Orkney might be limited and in some spots, the only immediate option is to go through the expensive satellite communication technology. To ensure the best signal availability from the mobile operator, multi-network (roaming) 4G SIMs can be the option to maximise connectivity in rural and hard-to-reach areas (assuming that at least one mobile provider can have coverage). It has been also found that some legacy charging stations which use 3G networks for their connectivity might be affected by the 3G shutdown and they require 3G-to-4G modem upgrades. Some manufacturers can easily upgrade the mobile connectivity module for some type of charging points, whereas, some other models may not be upgradable. As the age of the charging station along with its model and associated communication modem and its functionality will identify whether it requires replacement or upgrade.

LIST OF GLOSSARY

4G	The fourth generation of cellular network technology which is a type of broadband internet connection that uses fibre optic cables to deliver data directly to individual homes or buildings.
5G	The fifth generation of cellular network technology which can offer significantly faster speeds and more reliable connections than previous generations (1G-4G)
API	Application Programming Interface can be seen as a messenger between different software applications
BGAN	Broadband Global Area Network is a global satellite network that provides internet access almost anywhere on earth. It can be seen as a good option for remote locations where there is no cable or fiber optic internet service available
CMS	Central Management System is a centralized platform used to manage and monitor a network of devices or systems from a single location
xDSL	Digital Subscriber Line refers to a technology that uses existing copper phone lines to deliver broadband internet access
DSR	Demand side response is a tool to balance supply and demand for electricity and make the electricity network stable
eSIM	Embedded Subscriber Identity Module is programmable chip built directly into a device, replacing the need for a removable physical SIM card
EV	Electric Vehicle is a type of vehicle that runs on electricity instead of gasoline or diesel fuel
FTTP	Fibre To The Premises uses fibre optic cables running all the way from the service provider's exchange directly to your home or business and it is the highest tier of internet connection.
FTTH	Fibre To The Home is another term for Fibre To The Premises (FTTP) which can deliver superfast and reliable speeds through fibre optic cables running directly to users's home
HFC	Hybrid Coaxial Cable widely used broadband telecommunications network that combines optical fiber and coaxial cable
HITRANS	Highlands and Islands Regional Transport Partnership
ISO	International Standard Organisation
IoT	Internet of Things describes a network of physical devices that are embedded with sensors, software, and other technologies that enable them to connect and exchange data with each other and the internet
LPWAN	Low Power Wide Area Networks a type of wireless telecommunication wide area network designed to allow long-range communication using very little power and low data rates
Duty cycle	Duty cycle refers to the portion of time a signal or system is active within a single cycle
LTE	Long Term Evolution is a standard for high-speed mobile internet, often referred to as 4G LTE
MNO	Mobile Network Operator is a company that provides cellular network coverage and services to your mobile phone
Data rate	The speed at which data is transferred from one location to another, often measured in bits per second (bps)
Network latency	The delay in sending and receiving information over a connection
OCPP	Open Charge Point Protocol s a standardized way for electric vehicle (EV) charging stations to communicate with the central systems that manage them
RFID	Radio Frequency Identification is a technology that uses radio waves to automatically identify and track objects
UHF	Ultra High Frequency refers to a specific range of radio waves on the electromagnetic spectrum. The range falls between 300 megahertz (MHz) and 3 gigahertz (GHz), with wavelengths of about 1 meter to 10 centimeters
OFDM	Orthogonal Frequency Division Multiplexing is a way to transmit digital data over a wide range of frequencies
PLC	Power Line Communication is a technology that transmits data over existing power lines
QoS	Quality of Service refers to the management of data traffic on a network

CONTENTS

TABLE OF FIGURES

LIST OF TABLES

INTRODUCTION

Reliable and secure communication is one of the key requirements to ensure the flow of the services during the transition to the digitalisation in pursuit of net zero targets. A wide range of communications technologies can be used to enable the connectivity needed to monitor the EV charging stations. This report looks at the key technologies that can be deployed in hard to reach remote and rural areas, taking into considerations the key communication requirements for the EV charging infrastructure and identifying potential future technologies that could be used or easily deployed to meet the communications and cyber security requirements for EV charging in the Scottish Isles.

Low-latency, high-reliability, and wide-coverage wireless communication technologies are need to be utilised for EV charging infrastructure to enable information exchange required for services like charge scheduling, coordination, vehicle routing, authentication and billing and especially when they are designed for dynamic wireless charging infrastructure. As demonstrated in [1], fast, secure and reliable wireless technology for an EV requesting the charging service has to send a charging request with the EV information including EV speed, current location, destination, maximum battery capacity, periodic real-time updates on arrival time, expected charging time, and charging prices. Rural communities are often faced with limited or even non-existent of fast and reliable internet and wireless connections. The connectivity infrastructure barriers are often attributed to low population density, and lack of business use cases. EV charging infrastructure in the regions like the Highlands and Islands located in hilly terrains and hard to reach areas could be impacted by the type of connectivity options when 3G network is switched off. Considering the impact of 3G switch-off can only suggest that 3G is currently used by Councils' for EV charging provisions.

The switch-off of 3G networks in the UK represents challenges for various sectors, including EV charging infrastructure in remote and rural areas. But the switch off is also an opportunity to make room for faster and more reliable 4G/5G networks to be delivered within long coverage frequency bands previously used for 3G as being proposed by the some Mobile Network Providers (MNOs) [2]. Where it may be problematic for EV charging in remote and rural areas is when significant change on the device is required for EV chargers that are not compatible with 4G/5G. In this report, we have highlighted strategies that can be employed by HITRANS/Councils' to promote resilience in EV infrastructure.

Vodafone has switched 3G off across the UK and devices that don't support 4G will now use 2G instead. However, such an arrangement is temporary for some MNOs and 2G call and text-only services not being phased are not relevant for EV infrastructure [3].

Connectivity issue in Scotland according to Ofcom's document "Connected Nations Scotland" report published on 19 December 2023 shows that:

- Scotland still has the lowest 4G geographic coverage across all four MNOs of the UK nations. Visit Ofcom's broadband and mobile coverage checker for statistics on the coverage map of MNOs in the UK [4].
- 4G geographic coverage in rural areas across Scotland from all four MNOs remains poor in many parts of Scotland, particularly in areas like the Western Highlands and Islands.
- 84% of Scotland's landmass has coverage from at least one MNO (Dec 2023).
- 18000 premises in Scotland without broadband connection
- Some of the lowest levels of superfast broadband coverage in Scotland are found in the Orkney Islands, Shetland Islands and Comhairle nan Eilean Siar.

COMMUNICATION TECHNOLOGY: CONNECTING OUR WORLD

Introduction to the spectrum and communication applications:

The spectrum refers to the entire range of electromagnetic waves, categorized by their frequencies or wavelegths. It includes radio waves, visible light, and even X-rays. Think of it as a vast highway for wireless communication. As it is shown in Fig. 1, different frequencies have unique properties, making them ideal for specific applications:

- Radio waves: These low-frequency waves have long ranges and are used in radio broadcasts, legacy AM/FM radio, and walkie-talkies. These frequencies carry limited amount of information.
- Microwaves: With higher frequencies, microwaves transmit data efficiently over shorter distances. They are used in satellite communications, Wi-Fi, and cell phones. Microwaves frequencies carry a more amount of data compared to low Radio frequencies, as microwaves have more data rates (in bps) and better packing efficiency to carry more information compared to low radio frequencies.
- Other frequencies: Higher frequencies on the spectrum have even shorter wavelengths and are used for applications like radar, medical imaging, fibre optics and remote controls. These frequencies carry a massive amount of information.

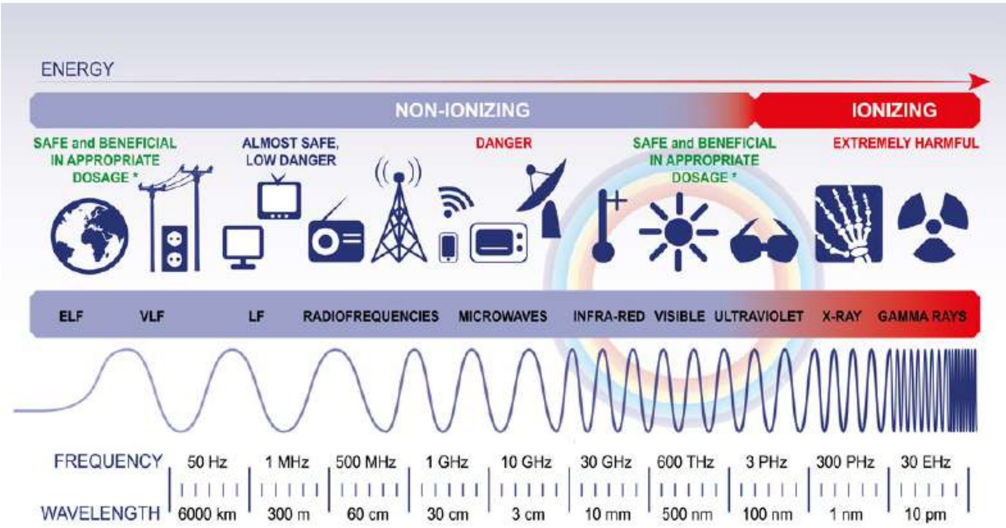

Figure 1 The electromagnetic spectrum, and its various applications based on the frequency allocation (source: IEEE)

However, there's a trade-off. While low frequencies may not carry as much data, they have advantages like better penetration through obstacles and longer range. Effectively managing this spectrum is crucial to ensure smooth operation of various communication technologies we rely on daily.

Connected World: A Look at Modern Communication Technology

Information and communication technology (ICT) is the backbone of our modern world. It's not just about phones and radios anymore. ICT encompasses all the tools and systems that allow us to share information, from the internet to complex business networks.

Over the past few decades, ICT has seen explosive growth, becoming an essential part of our daily lives. Mobile phones, the internet, and the Internet of Things (IoT) have revolutionized how we connect, work, and live. We can now communicate instantly across vast distances, fostering global communities.

The internet provides nearly unlimited access to information, keeping us informed on almost any topic. It also allows us to control appliances remotely, potentially reducing energy consumption in smart homes. Smart cities leverage interconnected systems for traffic lights, waste management, and electric vehicle charging, optimizing resource allocation.

While communication technology offers significant benefits, there are challenges to consider. Not everyone has access to reliable connections or the latest technologies, particularly in remote or hard to reach areas. Security risks and the potential impact on social interaction are also concerns.

Providing communication in remote areas can be expensive. The cost-effectiveness depends on the application. Critical infrastructure like substations might justify using expensive solutions like satellite services, while remote sensors might not.

This work focuses on providing communications to assets for EV charging stations which cannot currently receive cost effective connectivity using the business as usual solutions.

HIGH-LEVEL REQUIREMENTS FOR EV CHARGING POINTS

The US Department of Energy stated that the throughput required for home-based EV charging stations varies between 10 and 100 kbps. However, commercial EV stations require higher data rates. As the communication link is used not only to communicate between the grid and the charging station but also to carry charging-related messages as well as other information and associated services in various packet sizes (and then an effective communication link with sufficient bandwidth is needed).

The UK government introduced new regulations in June 2023 for public charge points, it is called the public charge point regulation 2023. The new regulations aim to enhance the charging experience of the EV charging points. The new rules highlighted the importance of several factors which should be considered and prioritised in any future deployment such as improving reliability, ensuring clear pricing and easing and securing the payment process. In addition, all public chargers with more than 8kW should be supported with contactless payments within one year also they should provide real-time information on their status. The new regulations will require more bandwidth and the communication link needed to be installed in any charging station should consider meeting the existing and future requirements in terms of payments and performance requirements.

For large sites, cable broadband that provides the necessary throughput is needed to meet the requirements in terms of billing, monitoring and connectivity with the grid. Smaller locations can use lower data rates of several Mbps networks. Wireless data plans should provide at least 10-20 Mbps speeds per charging post.

Responsibilities between the Destribution Network Operators(DNOs) and Charging Points Operator (CPOs)

As it is illustrated in Fig. 2, Grid Operators are responsible for maintaining the power grid to handle the extra load from EV charging, also they plan for future grid upgrades as EVs become more common. Moreover, they approve connections for new charging stations to avoid overloading the local grid. Whereas, CPOs are resposnse to install, operate, and maintain charging stations and set prices and manage billing for EV users. Moreover, the COP has other priorties such as:

- Reliable Charger Network:
- Ensure chargers are always available (high uptime).
- Remote monitoring and fixing of software issues to minimize downtime
- Support for various charger types and growing network demands.
- Use open protocols (OCPP, OCPI) for easy integration of different systems.
- Offer a variety of charger types for different needs (Level 2, DC fast chargers)
- Provide real-time information on charger availability and status

- Automate processes to reduce labor costs (fault detection, transactions)
- Implement smart energy management for lower energy bills during peak hours

So to ensure a reliable, secure and efficient charging networks for EVs, CPOs are the behind-the-scene to ensure they all communicate and function smoothly. As they setup the Network Setup via establishing the connection between charging stations, check the network's health, make sure stations can talk to each other and the central system. Additionally, CPOs keep the data flowing between stations and the central system, enabling features like remote monitoring, billing, and software updates.

DNOs and CPOs may also share some responsibilities, such as:

- Data sharing: Coordinating on grid conditions and charging demand for better management
- Standards and regulations: Following rules around safety, grid connection, and data privacy

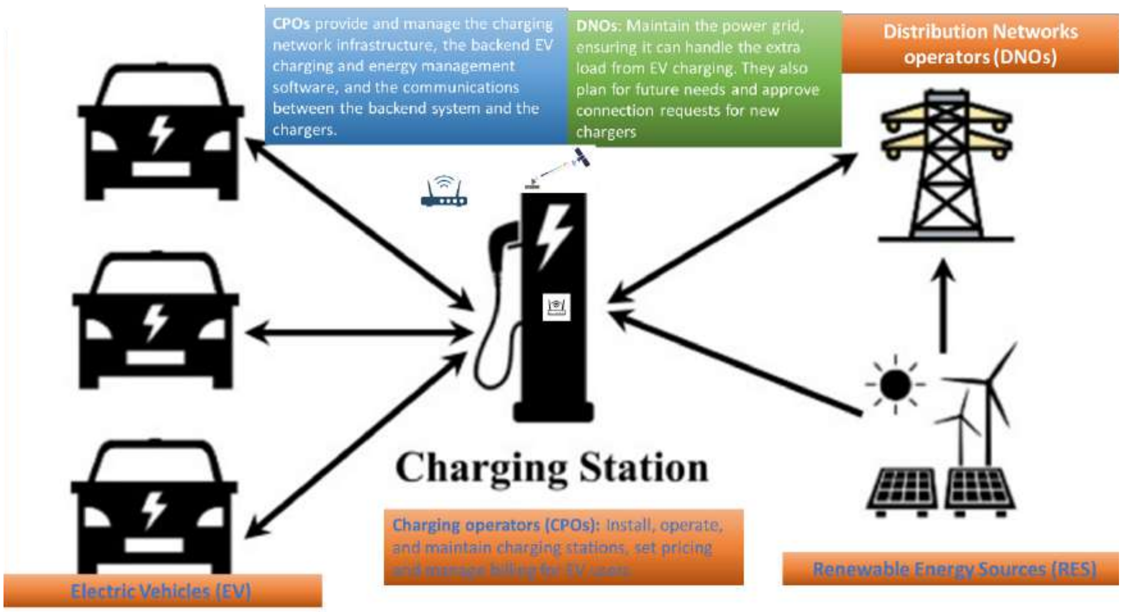

Figure 2 Key responsibilities between DNOs and CPOs

Comms Requirements for EV charging stations

The communication and data integration between the components of the EV charging system with the grid and the selection of suitable communications technologies require consideration of the following:

- Identifying the required data to be transmitted and its associated bandwidth needed to enable the functionality of the EV charging station and its associated services such as paying the consumable EV charging rate.
- Considering the cyber security and compliance with the UK NIS directives and IEC 62351. Encryption should be used for the exchanged data in addition to the authentication as well.
- Specifying the communication latency needed to enable the key functionality in terms of billing the customers and controlling the charging resources.
- Considering communication redundancy of some EV charging stations is essential but the associated costs might be a barrier.

- Ensuring the overall system reliability and optimum performance of the communication technology, as the performance of any chosen unproven communication technology should be tested prior to any field development. The communication technology should comply with the Ofcom regulations in terms of the available spectrum and operating frequency as well as meet the requirements of the Communications Act.

EV can strain power grids if charging happens at peak times, but they can also be part of the solution.

EVs act as distributed energy resources (DER) and can provide grid stability by storing and feeding power back into the grid as it is shown in Fig. 3. This requires infrastructure and planning to manage charging times.

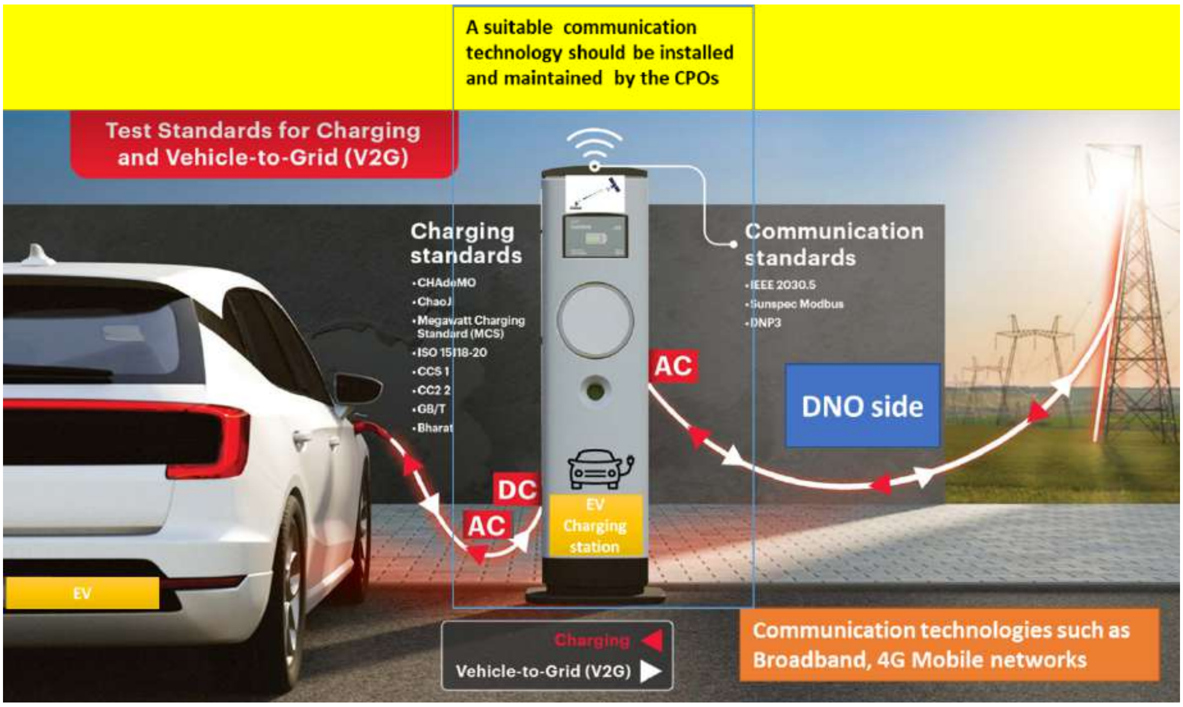

Figure 3 High level diagram shows how the EV communicate with the power grid

Regulations and policies are needed to support EV adoption and grid integration.

Secure communication between EVs and the grid is essential for safe and efficient grid management. Another words, EVs can be a key player in a sustainable energy system, but managing charging times and grid infrastructure is crucial.

Reliable and secure communication is the backbone of a smart grid that can efficiently integrate electric vehicles and maintain a stable power supply. This can be achived via:

- **Grid balancing and stability:** Communication allows for real-time data exchange between chargers, vehicles, and the grid. This enables "smart charging" strategies that adjust charging times based on grid demand and energy availability from renewable sources. This helps prevent overloading and blackouts.

- **Security:** Secure communication protects the grid from cyberattacks that could disrupt charging or manipulate energy flow. Standards like ISO 15118 ensure secure communication between electric vehicles and chargers. Further details about the Cyber Security Considerations will be explained in the next section.

A simplified overview of how the EV charing station Communiicate with Power Grid is shown in Fig. 3. As the EV communicates with the charging station through a charging port. This port uses standardized protocols for communication. The charging station acts as an intermediary between the EV and the grid. It uses communication protocols to receive information from the grid about electricity prices and demand . The grid transmits electricity to the charging station and receives data on energy usage. This data exchange allows for features like smart charging, where charging happens during off-peak hours to reduce strain on the grid. The previous process can not be excuted without a reliable and secure communication technology.

Cyber Security Considerations

Secure communications are needed to protect the charge stations to maintain the confidentiality and integrity of transmitted data, preventing unauthorised access. Additionally, there is a significant need to prevent potential security vulnerabilities by ensuring that EV network configurations can verify data inputs and discard unverified data. Complying with the cyber security standards for the EV industry such as IEC 62351, ISO/SAE 21434, and ISO/IEC 17001 is a must.

Various security techniques that can be used in the sector for authentication, management, encryption and certificate updates are listed below:

- The Internet Protocol Security (IPsec) authentication and encapsulation standard is widely used to establish secure VPN connections between charging network resources.
- Simple Network Management Protocol (SNMP) is used for monitoring the health of network EV devices, and it can provide data security and authentication.
- File Transfer Protocol Secure (FTPS) is used to securely transfer files between a client and a server on an EV network.
- Syslog is used by the field devices to send event messages to a logging server.
- LDAP (Lightweight Directory Access Protocol) is used to allow access to an application via its ability to store credentials in a network security system and retrieve them with the right password and decrypted key.
- TACACS (Terminal Access Controller Access Control System) is an authentication protocol that enables a remote access server to forward the login password to the authentication server to give access permission.
- Hypertext Transfer Protocol Secure (HTTPS) is used for securing the connection between the server and the web, ensuring the protection and privacy of the data.
- Transport Layer Security (TLS) is a security protocol that can provide end-to-end communications security when transferring data through EV networks.
- SMTPS (Simple Mail Transfer Protocol Secure) is a technique to secure the exchanged emails. It provides authentication and data confidentiality.

The above security protocols could be applied to any EV charging station, as some applications may not require all the above-listed protocols.

RELEVANT TELECOMMUNICATIONS TECHNOLOGY OPTIONS

A wide range of wire/wireless communications technologies can be used to enable seamless data exchange among EV charging stations and grid operators to enable effective dynamic load balancing and payment services. The suitability of wireless technologies such as LPWAN (i.e. NB-IoT, RPMA) and BGAN satellite communication along with G3/G4 and private LTE varies based on their availability (rural/urban) and the main applications (control/monitoring). In this section, the technologies to be considered will be described along with their advantages, disadvantages and relative costs. The communications will only cover the links between EV charging stations and grid management systems.

Broadband communication technologies are among the most used technogies to connect the EV changing stations to the grid, nd they rely on various methods for transmitting large amounts of data quickly over long distances. Two main categories are considered namely wired and woreless Broadband. The first (i.e., the wired broadband) uses physical cables to transmit data such as:

- Fiber Optic Cable (FTTx): Fastest and most reliable option.
- Hybrid Coaxial Cable (HFC): type of internet connection that combines fiber optic cables with traditional coaxial cable and commonly used by cable TV providers and internet access.
- Copper Cable Digital Subscriber Line (xDSL): Uses existing phone lines we have at homes to deliver broadband internet access but the speed is slower than fiber.

Whereas, the later (i.e., the wireless Broadband) transmits data through radio waves over various technogies such as:

- Cellular Network (4G/LTE, 5G): Uses cell towers for mobile internet.
- Satellite: Provides internet access to remote areas but can have latency issues (Not appicable for some critical applications that require a very low latency).
- Wi-Fi: Short-range high-speed connection for homes and offices.

More details bout the available communication technogies that can be used to connect the CPOs and the DNOs are listed in the following sections.

Breakdown of EV Charging Station Components and Integration:

- Hardware: The station itself includes communication hardware like an antenna, specific to the chosen technology.
- Software: The right software manages data securely and follows a communication protocol (like OCPP).
- Router: A secure router is needed, not necessarily a "firmware" router, to manage communication with the internet.
- Integration: During Wi-Fi connection, the antenna transmits and receives data. The router translates it and forwards it securely to the internet for further communication with the charging network.

Cellular connectivity is another option for data transmission in electric vehicles (EVs). A high-level breakdown of the hardware and software integration for 4G mobile EV connectivity shows that there are several ways hardware, software, EV charging stations and mobile 4G networks work together:

- **Connectivity**: Mobile 4G networks provide internet connectivity to EV charging stations through cellular routers with SIM cards. This allows stations to communicate with central management systems.

- **Real-time Data and User Interaction**: The 4G connection enables real-time data transfer between stations and software platforms. This allows features like:
    - Driver access to information on nearby stations and their availability.
    - Remote monitoring and management of charging stations by operators.

A real example from Advantech for industrial networking products suitable for EV charging stations is shown in Fig. 4. The hardware consists of the following components:

- Robust Ethernet switch
- P-Fail relay for network-based switch status monitoring, improving management efficiency.
- 5G NR router hat provides high speed, low latency, and high availability for IoT and eMBB applications like camera and security systems.
- Ethernet electrostatic discharge protection to mitigate the effects of strong electromagnetic waves produced by EV charging.

A dedicated software enables the above components to work together, allowing for management and monitoring of individual charging points

Hardware and Software Integration for **Satellite-Connected EV Stations**:

Hardware: A satellite modem needs to be installed at the charging station to communicate with the satellite network.

Software: New software is required to manage communication with the satellite network and translate data for existing charging station software (often using OCPP). This software might also integrate with existing IoT systems for monitoring and control.

Challenges: Integrating new hardware and software requires ensuring compatibility with existing systems while handling the unique data transfer needs of satellites.

Satellite communication can offer GPS and location services, and it also offers a wide range of data rates depending on the service and technology used. This makes satellite communication a good option for getting location services in remote areas where there is no cell phone signal as it can be shown in M2M/IoT satellite communication section.

Mobile networks

Mobile network operators such as Vodafone, O2 and EE run different technologies such as GPRS/4G and they are in the process of deploying 5G technology. Such technologies are almost available everywhere in urban areas and do not have bandwidth limitations (compared to the LPWAN technologies) and the other restrictions that LPWAN suffer from. As such, this is a viable option for communications. Regarding mobile signal penetration, mobile networks which operate in different frequency bands will have different penetration capabilities. For a spectrum with a frequency band of more than 900 MHz (i.e 1800 MHz and 2100 MHz bands), the penetration may not be sufficient for some hard-to-reach areas and link boxes. For mobile base stations which operate with lower bands (i.e 800 and 700 MHz), the penetration can be similar to that of NB-IoT.

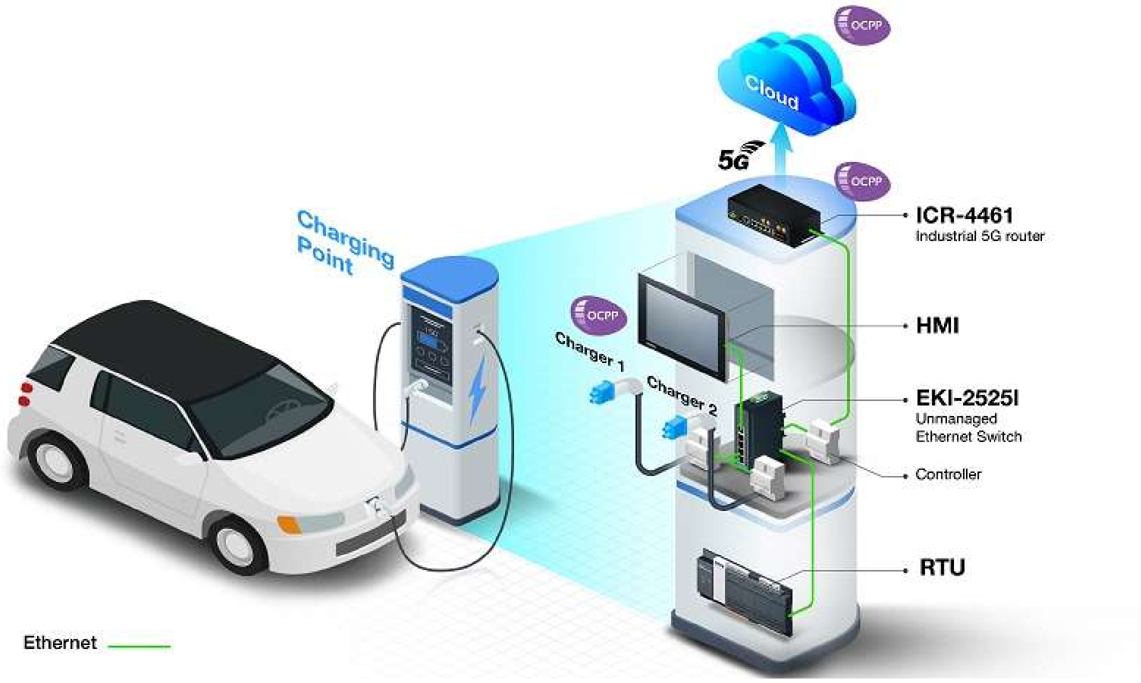

Figure 4 Hardware and software integration from Advantech

Private wireless communications such as Private LTE can be an alternative choice as the bandwidth requirements could be easily met provided that the DNOs obtain sufficient spectrum to accommodate LV monitoring traffic including the EV charging stations.

LTE/4G technology is widely operated by a commercial mobile network or deployed as a private LTE network to deliver scalable and suitable data rates for utility and many industry applications. Using LTE/4G technology (subject to signal availability) can offer flexibility advantages to ensure the right connectivity of the EV charging stations. Details about the coverage are highlighted in the next section.

FTTP (Fiber to the Premises) Broadband

Openreach is working on expanding the fibre optical connectivity to new homes in the highland namely in new premises and houses in Gott on Shetland, Kirkwall on Orkney, Stornoway on the Isle of Lewis and Bowmore on Islay. The Fiber to the Premises service can offer superior capacity and more reliability also it is capable of broadband speeds of up to 1Gbps. Openreach is facing some challenges in bringing FTTP to these island sites, like shipping out specialist equipment to Shetland to blow the delicate, glass fibres through underground piping. So this could slow the process of installing the FTTP. The Scotland’s Reaching 100% Fibre Broadband project with Openreach using FTTP technology is expected to reach full completion in March 2028. The original plan was supposed to cover 12,000 premises with FTTP by 2026.

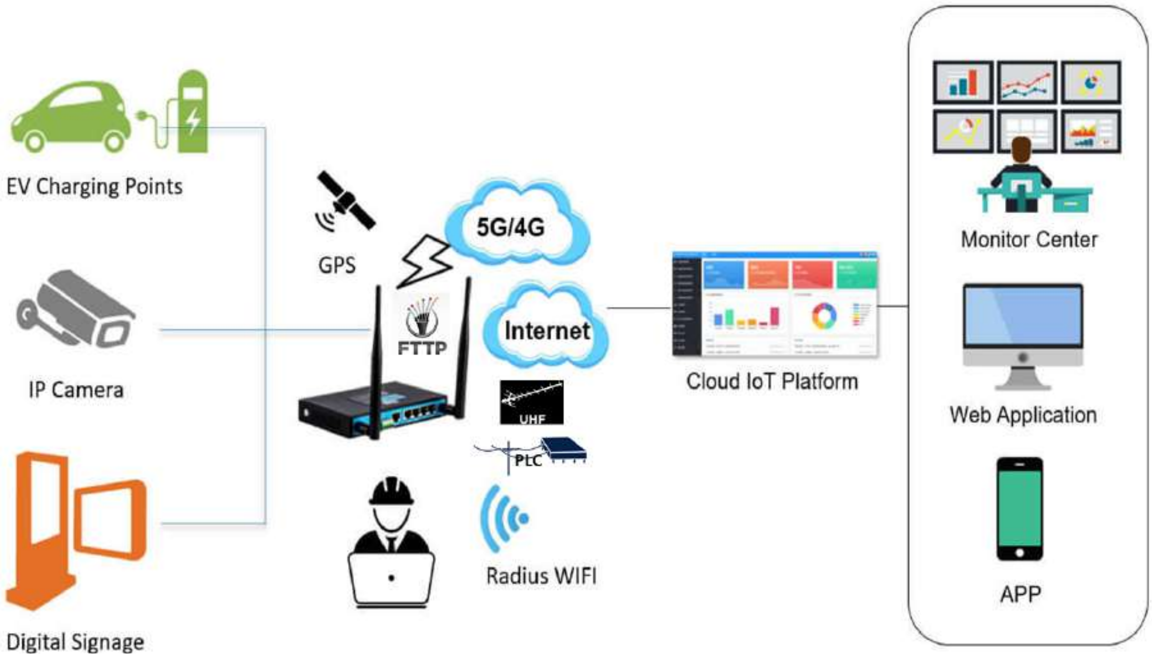

Figure 5 Various communications technolgies can be used to conect the EV charging stations (source: bivocom)

Although the service is available in too many remote areas in the western and northern Isles including Orkney, the availability of broadband is still below expectations. FTTP can be an option to connect the charging point to the grid if the service is available as it is cheaper than the satellite (The average price for FTTP services in the UK varies between £25 to £50 per month depending on speed and internet service provider).

Fig. 5 shows several communication technogies which can used to connect the public charging srtations with the grid.

Low Power Wide Area Networks (LPWAN)

LPWAN technology supports long-range communication, which allows the deployment of new types of services. Long Range (LoRa), Sigfox, Random Phase Multiple Access (RPMA) and NB-IoT are the major technologies in the LPWAN space and they have been developed mainly for IoT and Machine to Machine (M2M) applications. Each technology has its own advantages and at the same time suffers from many drawbacks. Even without the need for very low latency to enable the connectivity between the grid and legacy charging station, new charging stations and services such as dynamic wireless charging and grid connection for DC fast charging require low latency and reliable connectivity with the grid in order to minimize delays in transmitting payment data and enable real-time transaction processing. Some technologies such as LoRa and Sigfox are not suitable due to the following reasons:

- Data cannot be transmitted continuously because of spectrum regulations and the duty cycle restrictions (typically 1%).
- The performance (i.e latency) degrades the further away the end devices are from the gateway.
- Bandwidth and data rate limitations (less than 50 kbps).

- Although both technologies can support 2 ways communications, the downlink communications from LoRa-Sigfox gateway to the sensors are limited.

- Not suitable for any control application.

- The required low latency of some EV services cannot be achieved.

For any real-time service where real-time operation requires low latency, both LoRaWAN and Sigfox technologies cannot be considered an optimal solution for the EV charging station.

A licensed option of the LPWAN technology is NB-IoT/LTE-M, which was developed based on the 3GPP Release 13 specifications using a subset of LTE standard with a much narrower bandwidth (180 kHz compared to LTE's broader bandwidth). The technology can be operated over 4G/5G spectrums, which can offer good coverage in most residential areas. The penetration of the NB-IoT/LTE-M can be better than the other LPWAN technologies as some mobile operators run the technology in the 700MHz frequency band. The limited bandwidth of NB-IoT (200 kbps) and the extra delay caused by the signal quality (where the coverage is poor) are the main disadvantages of the technology. If TCP is used to transmit and exchange messages, NB-IoT latency may not meet the packet retransmission timeouts (since NB-IoT is a best-effort delivery mechanism) [5].

Another LPWAN technology is RPMA which is an unlicensed technology that operates in the 2.4 GHz band and provides bandwidth of around 38kb/s per access point. It does not have a duty cycle restriction. This means that the throughput could be divided across any number of distributed devices. Such flexibility may not be acceptable for every EV charging station application. However, the penetration of the signal without an external antenna is worse than NB-IoT. Moreover, the limited available shared bandwidth may not be sufficient for all future applications and the technology is not yet deployed in the UK market. Although the available bandwidth of NB-IoT and RPMA could meet the requirements for the EV charging station, the penetration of the signal to the charging station without an extended antenna is an issue.

In summary, LPWAN technologies could be a suitable option for connecting EV charging stations, especially for transmitting essential data due to several advantages:

- Low Power Consumption: LPWANs are designed for battery-powered devices, ideal for remotely located charging stations where frequent maintenance might be impractical.
- Long Range: LPWAN signals can travel long distances, ensuring connectivity even in rural areas where cellular coverage might be limited.
- Cost-Effective: LPWAN modules and network access are generally less expensive compared to traditional cellular solutions.

However, LPWANs have limitations in data transfer rate. They are not ideal for transmitting large data files but work well for sending small packets of information like:

- Station availability
- Charging status
- Energy usage data

LPWAN focuses on low data rates, and secure financial transactions typically require more data transfer than LPWAN can efficiently handle. Therefore, LPWAN can be part of the solution, but cellular networks or other solutions are needed for secure payments as they are suitable for high-bandwidth applications like software updates or video surveillance, cellular IoT might be a better option alongside LPWAN for a comprehensive solution. The cellular IoT data allows for:

- Remote monitoring and management of charging stations.

- Optimizing charging efficiency based on grid conditions.
- Providing real-time information to EV drivers about station availability and wait times.

Power-line communication

Power Line Communication (PLC) can be a very cost-effective solution for the communication between the EV charging station and the Grid management system. The reliability of the connection, however, should be assessed to ensure that the Quality of Service (QoS) could meet the requirements of future EV charging points.

There are two PLC technologies, namely Broadband over Power Line (BPL) and low-frequency narrowband PLC. Broadband PLC allows a data rate of several Mbps, which operates in the 2-30 MHz band to support applications with high data rates. While a low-frequency narrowband PLC can support applications with data rates of up to 128 kbps. A recent test at the PNDC on the BPL technology showed that the BPL connection is reliable and can be used to transmit data between secondary substations. The obtained results showed that the average data transmission speed from the test was about 7.8 Mbps, and the average latency was stable.

The main advantages of the PLC technology for data transmission between the EV charging points and the grid are:

- No new communication link infrastructure (i.e cables/antennas) are required since PLC uses the existing power cable to communicate between the EV charging station and the grid.
- The technology does not rely on any radio penetration restrictions (it can reach 1.7km in LV networks [6])
- PLC is independent of third-party providers (i.e. no monthly fees).
- Some field tests on the low voltage system have measured ranges of up to 1 mile.

The main disadvantages of the PLC technology are:

- PLC is subject to the noise imposed on power lines and is subject to signal corruption by signal-distorting transformers.
- The bandwidth offered by the PLC is dependent on the signal-to-noise ratio, so the noisy environment of the power lines could affect the quality of the connection.

PLC is however still an appropriate technology for a number of applications and is used by DNOs. Some successful use cases for Broadband Power Lines (BPL) provided the connection to transfer data from field devices (i.e. smart meters) to the substation. It is used by the power utilities in Germany as an option for devices which are located in a basement and are unreachable by wireless communication technologies [8-10]. Many projects for BPL for smart grid applications have been delivered [8]. These projects enabled metering services and network management (including 11kV networks) via BPL.

BPL can use various techniques to eliminate the noise such as Orthogonal Frequency Division Multiplexing (OFDM) and Smart Notching. Another ongoing research on PLC technology suggests that the filtering system can be utilised to reduce the interference in the 120 – 150 kHz band that is introduced into the network by receivers [6, 7].

BPL could work for up to 4 KM. So 500 – 800 metres which is the upper limit between devices in a typical distance between substations and link boxes indicates that BPL is expected to function adequately. Other considerations such as the topography and nature of the area to be connected (rural or urban), age and type of power cables, availability of installers (own or contracted) and access to the grid will affect the cost of the installation.

Although, BPL seems to be a promising communication technology to connect the EV charging station to the grid management system in the hard-to-reach area. Further empirical and field trial evidence of the reliability of the connection can be done at the **PNDC to validate some of the research claims**.

UHF (Ultra-High Frequency) Radio

The Ultra High Frequency (UHF) radio networks are very popular and their use can be found in many applications across various utility and transport sectors. The UHF technology operates on frequencies between 300 MHz and 3 GHz. It is two-way communication which can enable reliable two-way communication by transmitting and receiving signals using UHF frequencies. The key advantages of UHF signals in the shorter wavelengths which allow better penetration through obstacles and improved signal quality in urban environments.

A successful use case of UHF technology is the use of UHF radio connection to provide communications for substation SCADA RTU in hard-to-reach areas where other technologies such as optical fibre, 4G/5G mobile communication and other connections such as satellite communications are not economically possible. The UHF radio connections are currently in operation to monitor various types of power applications such as substations, they are widely used in remote sites as point-to-multipoint systems operating in the 400MHz spectrum.

UHF (Ultra-High Frequency) communications could be considered as an option to be used in the EV charging infrastructure. As the UHF is a private network reliable communication which can implement low-cost, reliable local communication with sufficient range and penetration capabilities for EV charger systems. In order for EV charging to communicate with the grid management system using UHF technology, HITRANS must ensure that it is using a charging station with the right communication model that supports the UHF and ensures compatibility with the charging point and compliance with the related charging standards in addition to full compliance with the cyber security standards.

M2M/IoT satellite communication

Due to its wide geographic coverage, satellite communication has been used as a suitable alternative for power system automation for reaching remote substations. Satellite IoT and SCADA solutions such as Broadband Global Area Networks (BGAN) M2M technology could offer an option for IP-based connectivity services and could be suitable for managing remote assets such as EV charging stations in rural and hard-to-reach areas. BGAN has global coverage and data rates of up to 448 kbps with a latency of around (800 ms). It suffers from some drawbacks such as the impact of weather conditions, high latency and high cost which limit its use. In the absence of other technologies, BGAN could be used for reliable connectivity of LV charging stations with the grid. Currently, the cost of using Satellite for data transmission is expensive, where the cost of carrying 1 Byte can be several folds higher than any alternative technology.

A comparison of different available wireless technologies for LV monitoring are summarised in .

Table 1 Comparison between different available communication technologies

	LPWAN			FTTP	LTE Private LTE	UHF	PLC	Satellite M2M/IoT
	LoRa Sigfox	NB-IoT	RPMA					

Peak data rate per base station	50 Kbps	250 kbps	31 kbps	36Mbps-1Gbps	More than 3 Mbps (based on the bandwidth)[1]	Up to 1 Mbps for 200 KHz (based on 256 QAM)	128 kbps	448 kps
Network Latency	More than 10s	1-10s based on coverage	5 - 40s based on coverage	less than 5 ms	Less than 100ms	Less than 2 seconds	less than 1 second	800 ms
Relative Cost	Very Low	Very Low	Very Low	High	Medium	Medium to High	Low to medium	High
Factors influencing availability	Location/ availability of the gateway	Mobile operator coverage	Location of the base station	Mesh node location	Mobile operator coverage	Location of the master station	Local installation	Available
Support future deployment (adaptive demand response, EV storage and DER management)	NO	Very Limited	Very Limited	Very Good	Very Good	Limited	Limited	Good
Suitability to the EV Home/ destination/journey charging in	Limited to some key features Such as Status update	Limited to some features Such as Status update and availability	Limited to some key features Such as Status update	All features, including secure payment, real-time monitoring with HD video, and grid management, are supported	All features, including secure payment, real-time monitoring with HD video, and grid management, are available	Key features such as payment processing and charging station status updates	Key features such as payment processing and charging station status updates	Key features such as payment processing and charging station status updates
Key providers and Primary manufacturers	WNDUK for SigFox, Alliot and Netmore Group for Lora	Vodafone & Soracom and Alliot Technologies	Trilliant SecureReach® LPWA	BT, Virgin Media, Openreach, VOdafone and talk talk	Mobile networks operators Vodafon, EE,O2, EEThree and EE	Racom & Westica,	Infineon Technologies & STMicroelectronics	Inmarsat Plc & Starlink

There are a few categories of communication data that need to be considered separately for EV charging points:

- Basic authentication/authorization of a charging session: This is typically in the order of 1 - 5 seconds; only applicable for public charging points.
- Realtime reporting of charging session data to backend/user app to enable tracking of the session status: This is typically slower and takes around 10 - 300 seconds.

- Demand response (DR) instructions: Which is only likely for destination & home chargers - this depends on the specific Demand side response (DSR) product/market but it could be anything as low as 2 seconds for ancillary services to up to 15/30 minutes for balancing services on the wholesale market.

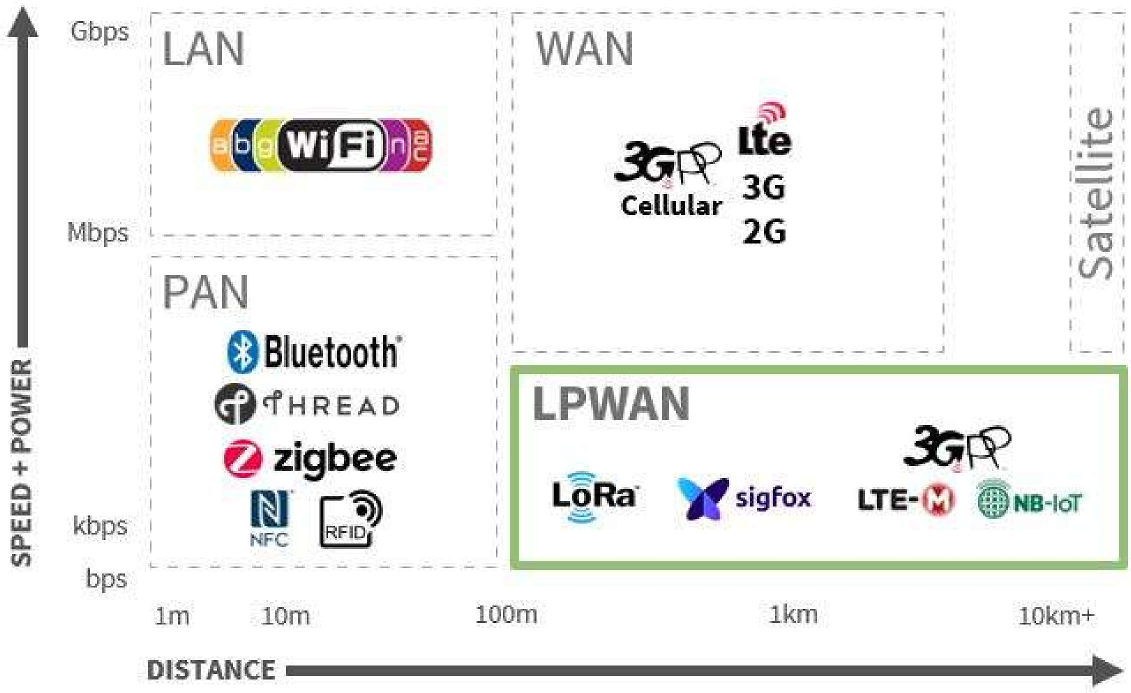

Figure 6 Wireless Technologies in IoT applications (source: Allion)

A variety of wireless technologies cater which are in use in exisiting IoT applications are illustrated in Figure 6. Whereas, table 2 shows different EV charging scenarios that rely on various communication technologies, as the recommended technology depends on the data being exchanged and the charging system's functionality and its key requirements.

There is no direct relationship between kWh output and communication requirements for EV chargers. However, communication protocols enable chargers and cars to negotiate the appropriate charging speed based on factors like battery capacity and available power. kWh output (charging speed) indicates the rate of power delivery (e.g., 7.4 kW or 22 kW) and impacts charging time. Data rates and network latency are not critical for home chargers, as overnight charging at slower speeds (e.g., 3.6 kW) is ideal. Public chargers offer more flexibility and may require negotiation for faster charging. DC Fast Chargers (50 kW to 300 kW) enable rapid range extension (15-30 minutes) during long journeys. In summary, higher kWh output translates to faster charging speeds. Home chargers prioritize convenience, while public and DC Fast Chargers offer options for on-the-go situations. More details about the EV charging levels are listed in the appendix.

Table 2 communication technogies for various EV charging

	Home Charging	Destination Charging	Journey/Travel Charging	Notes

Data Rates for EV Charging Stations	Data typically isn't required for basic charging. Some chargers offer Wi-Fi for features like monitoring or scheduling, but it's optional.	May require a small amount of data for payment processing or station communication. It's not a high-bandwidth need	May require a small amount of data for payment processing or station communication. It's not a high-bandwidth need	Data rates for Key EV charging's features wouldn't be high. An internet speed of 3Mbps will be sufficient enough to process secure payment, station status, and any firmware updates.
Recommended comms technology	A standard home internet connection (typical Mbps range) would suffice (i.e., WiFi)	Connection is needed for features like payment processing or station status updates. Data rates obtained from various technologies can be enough to enable these features such as Broadband, FTTH, and Mobile Communication 4G	Connection is needed for features like payment processing and station status updates. Data rates obtained from various technologies can be enough to enable these features such as Satellite communication in the Hard to reach areas	

Unreliable communication networks are a major challenge for public EV charging stations (CPs). This disrupts functionality in two ways:

- **For EV users:** Status updates disappear on the CP app, preventing user verification and charging initiation. This can be frustrating.
- **For CP operato**rs: It's difficult to distinguish between a CP failure and a communication issue (both appear offline). This delays identifying actual malfunctions, especially in remote areas prone to dropped connections.

It is good to mention that, latency is not directly relevant here. It might be crucial for different load balancing scenarios (not cloud-based).

Reliable communication is essential for a smooth user experience and efficient CP management (as poor connectivity can lead to user frustration and hinder EV adoption). It aligns with government regulations for public EV charging infrastructure.

DIGITAL CONNECTIVITY ISSUE IN SCOTLAND

A recent report published on 21 December 2023 and titled “Rural Scotland Data: Dashboard Overview” presented data on a range of issues that impact rural Scotland. The report stated that Scotland's digital connectivity is limited, with around 8,000 residential and commercial premises in rural areas lacking decent broadband or good 4G mobile coverage in 2022. Superfast broadband coverage is 79% in rural areas compared to 99% in urban areas, and gigabit-capable coverage is only 34% in rural areas. Scotland has the lowest geographic 4G network coverage of any UK nation, with in-vehicle coverage on major roads being 96% for 4G and 99% for voice calls.

An older report by the Scottish Government from 2021 has also revealed that residents of the remote islands of Orkney and Shetland are experiencing poor internet and mobile phone connectivity. The National Islands Plan Survey revealed that only 27% of Shetland Outer Isles residents said their home internet connection was fast enough to access the internet online, compared to 66% of Shetland Mainland residents. The survey also found that 62% of island residents agreed that their internet connection at home was reliable, but with a significantly lower agreement in Shetland Outer Isles (30%) and Orkney Outer Isles (35%). The survey also revealed that 60% of island residents agreed that they had a good mobile phone signal in their home, while 56% reported a good signal in their local area. The report also revealed that 96% of island households reported having access to the internet from home, with older residents reporting slightly lower levels of access than other age groups.

Ofcom - in its latest document titled "Connected Nations Scotland" and published on 19 December 2023 Report 2023 included the below statistics about the connectivity in Scotland:

Note that Scotland still has the lowest 4G geographic coverage across all four MNOs of the UK nations with 4G geographic coverage in rural areas across Scotland from all four MNOs remaining poor in many parts of Scotland, particularly in areas like the Western Highlands and Islands. The 84% of Scotland's landmass has coverage from at least one MNO (Dec 2023) leaving approximately 18000 premises in Scotland without a broadband connection. Some of the lowest levels of superfast broadband coverage in Scotland are found in the Orkney Islands, Shetland Islands and Comhairle nan Eilean Siar.

Mobile Coverage availability in Highlands and Islands

The Highlands and Islands, including the Western Isles, Shetland and Moray suffer from relatively poor 4G coverage compared to other areas in Scotland. As shown in Figures 7-11, specific data on coverage in Moray vary based on the location within the region and the network provider. As can be seen from Figures 7-9, the existing mobile coverage in Moray is not good and some rural areas may not have any availability from any mobile provider.

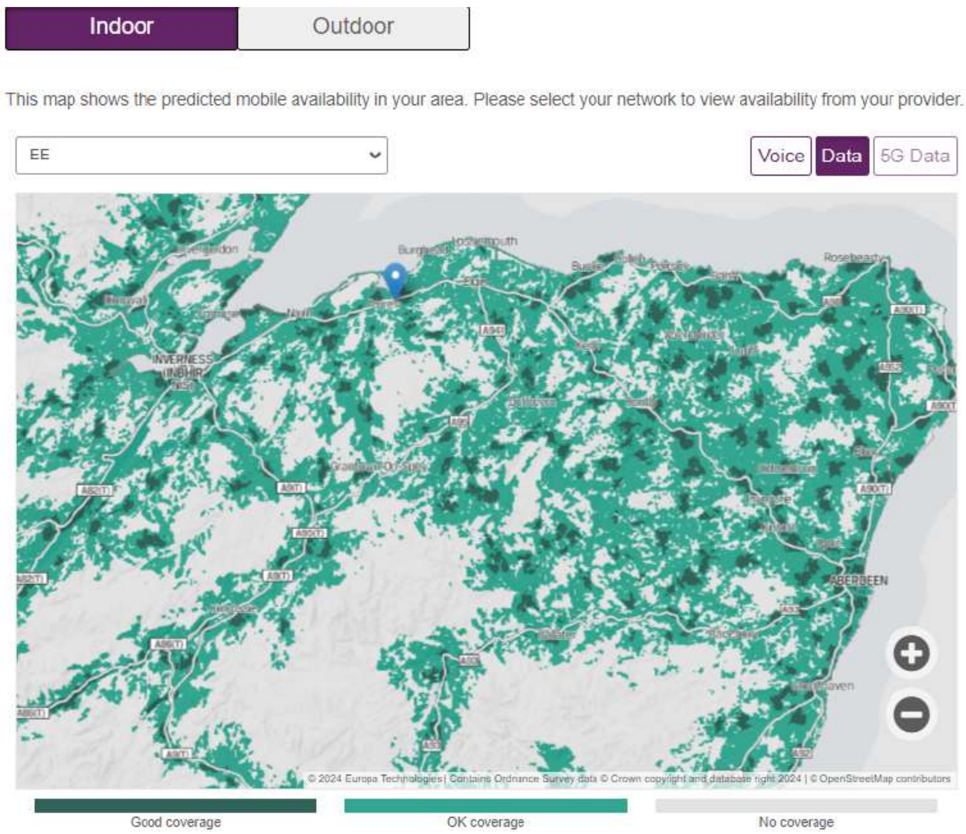

Figure 7 Indoor mobile coverage map for EE (Moray - source Ofcom)

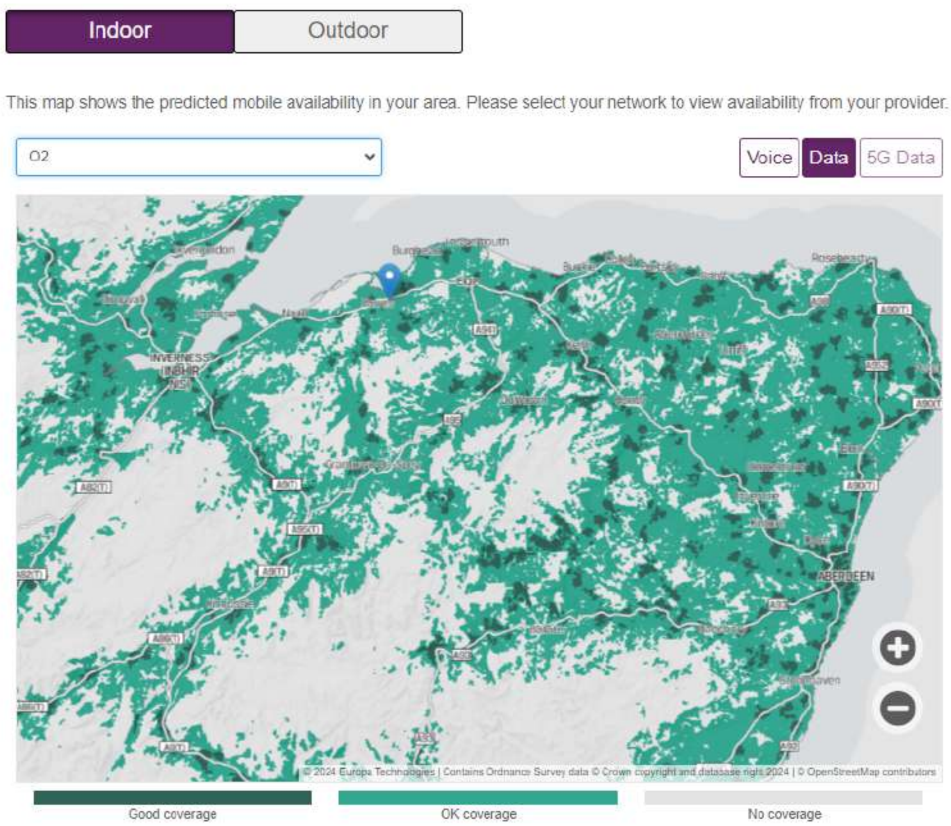

Figure 8 Indoor mobile coverage map for O2 (Moray - source Ofcom)

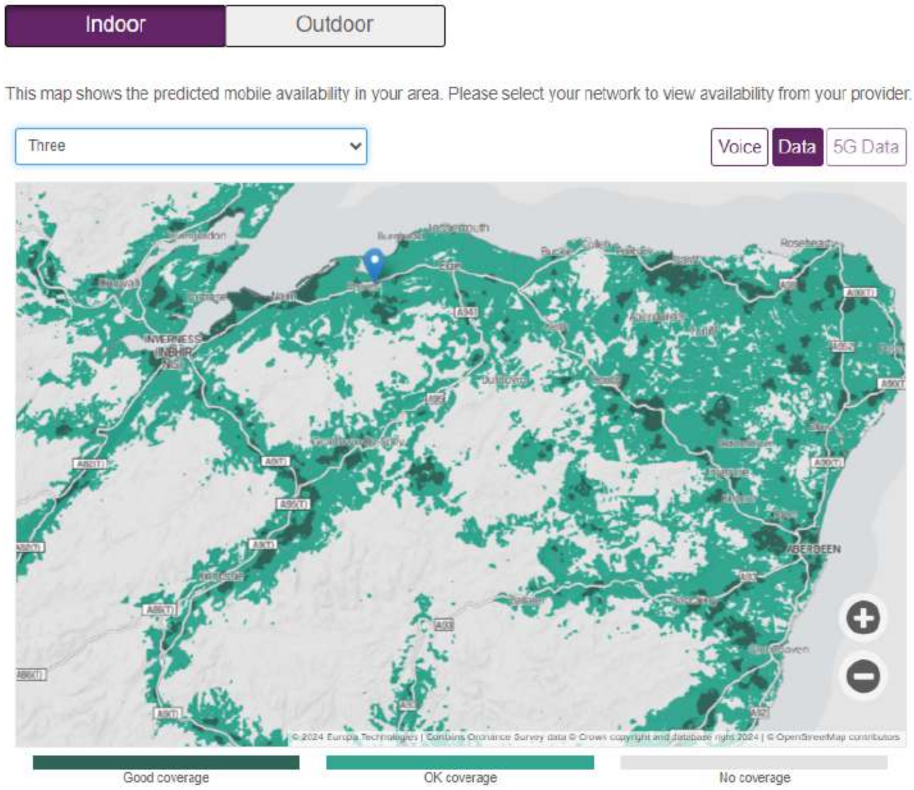

Figure 9 Indoor mobile coverage map for Three (Moray-source Ofcom)

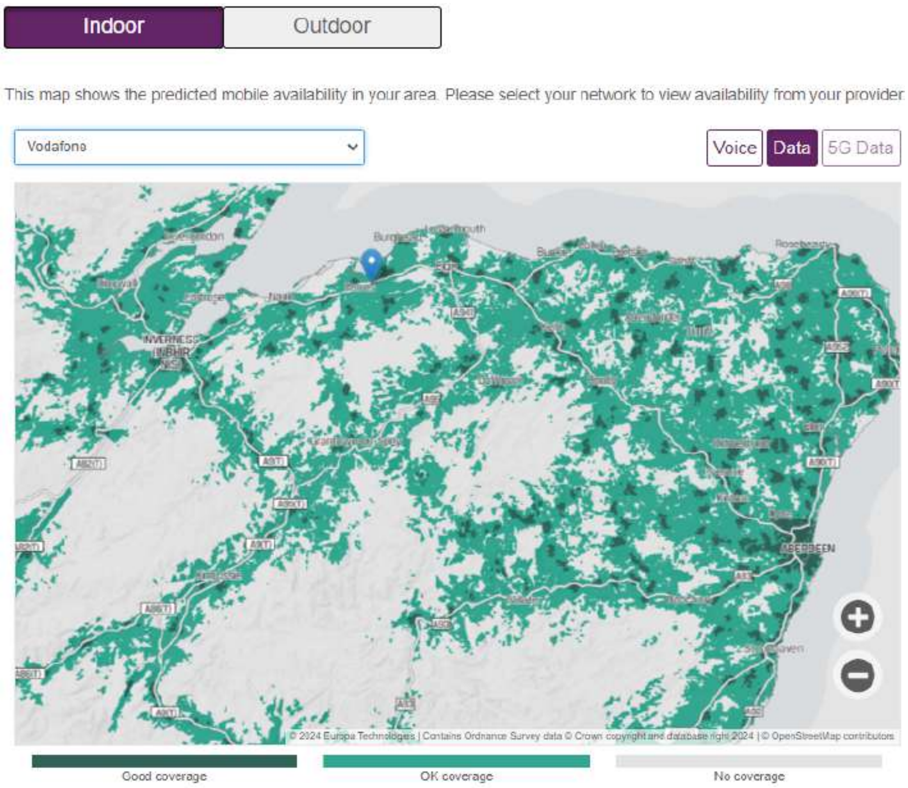

Figure 10 Indoor mobile coverage map for Vodafone (Moray-source Ofcom)

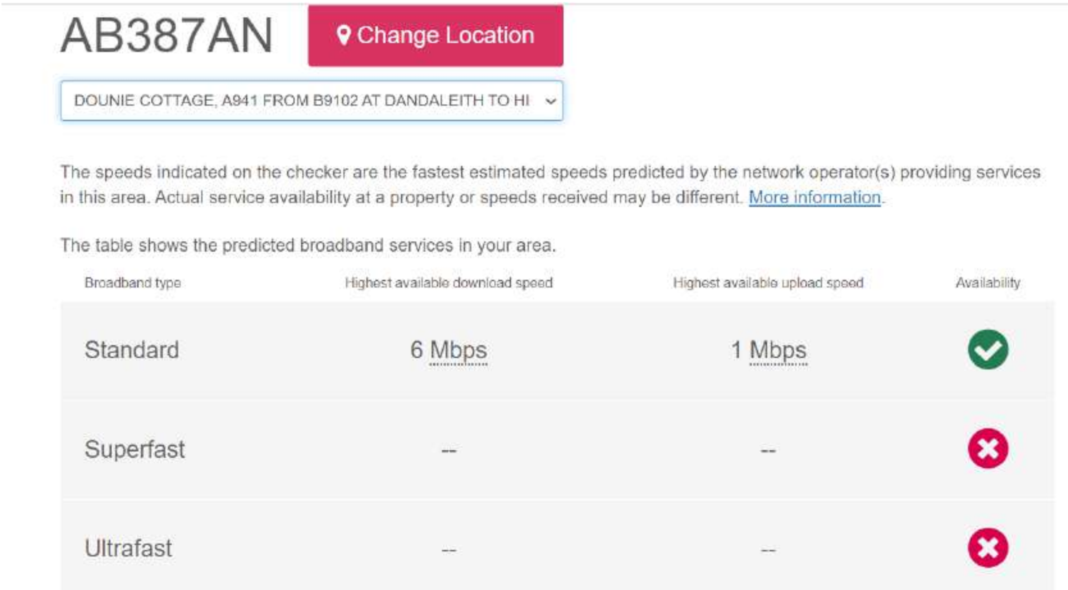

Figure 11 Broadband availability is also limited in lots of areas in Moray (Aberlour- Source: Ofcom)

Further details and more figures on the availability of mobile coverage in the Shetland and the Western Isles are shown in the appendix.

KEY FINDINGS AND RECOMMENDATIONS

In this section, the summary of answers to the questions from Hitrans will be highlighted and discussed along with some recommendations from the study.

This project focuses on answering the following questions:

What are the key requirements to enable the functionality of the EV charging by reliable and secure communications?

Enabling the functionality of the EV charging infrastructure requires reliable and secure communications infrastructure to facilitate various essential operations. Below are the key requirements of the technologies that HITRANS adopts to achieve reliable and secure communications for EV infrastructure:

- **Data Encryption**: The exchanged data between the EV charging infrastructure and the cloud/grid should be encrypted, as for example user information and billing details cannot be sent without encryption.
- **Infrastructure Authentication**: Authentication is needed to enable every EV network infrastructure to be identified and verified to prevent any unauthorised access. Secure communication protocols such as Open Charge Point Protocol (OCPP) and ISO 15118 can ensure a secure connection between the EV station and the grid. Radio Frequency Identification (RFID) cards and plug and charge can also be used for authentication.
- **Data accuracy**: Data privacy and trust is needed during any communication from/to the EV charging station to ensure the integrity of the exchanged data which may include details such as billing, charging schedules and grid management traffic.
- **Reliable Communication Infrastructure**: Reliable connectivity is needed in order to ensure the functionality of the EV charging stations in terms of software update and remote monitoring and their appropriate and secure operation.
- **Latency**: Low end-to-end communication latency is needed to enable the car to respond quickly to any change in the condition with a minimal delay needed when a payment transaction is required. As payment systems require fast, reliable and secure communication links between the EV charging station and the grid management system.
- **Cybersecurity:** Ensure secure communication protocols between charging stations and authorized devices to prevent unauthorized access or data breaches
- **Resilience and redundancy:** Implementing multiple communication technologies will ensure reliability, availability, and continuity of service and establish redundant network connectivity for EV charging stations to ensure continuous communication with the management systems, billing platforms, and monitoring tools during network failures or outages.
- **Interoperability:** The communication technologies must support through open standard protocol different charging stations, EVs and the management systems to effectively exchange data regardless of the manufacturer, brand, or communication protocol used.

What are the recommended communication technology options to be used in connecting the EV charging stations in the hard-to-reach areas?

Building a future-proof charging EV communications infrastructure is key to enhancing rural EV charging resilience. When there is an unexpected event like power outages and fluctuations, the communications network can be leveraged to ensure uninterrupted charging services, balancing demand and supply, and managing containments and technical issues.

Similarly, EV charging stations require reliable connection to the central management systems to allow essential functions such as recording energy consumption, remote monitoring and calculating the charging and payment rates. The essential data needed to be sent to the cloud/EV charging management software are the available power, current EV Charging Load, information about peak energy usage times charger status updates, payment processing and user authentication. The data rate or the bandwidth needed is low and not very demanding but reliability is a must.

<u>Upgrade to Private and Public Mobile (4G/5G)</u>

Transitioning to newer cellular technologies like 4G and 5G can even provide faster and more reliable connectivity for EV charging solutions but dependent on application requirements, costs and interoperability. Running an upgrade will ensure that EV charging infrastructure remains operational even after the 3G network shutdown. With 4G/5G possibly to be deployed in the 3G frequency band as being considered by some MNOs, wide coverage and good reliability, even in some hard-to-reach locations would be achieved. For the best mobile signal quality and wider coverage, HITRANS should consider MNOs with plans to use the low-frequency band for 4G/5G deployment (i.e., less than 900 MHz is essential to enable a wider area from one mobile radio mast). Depending on the class of service, upgrading to 4G/5G can mitigate the immediate impact. However, 5G cellular networks deployed at high frequency are only suitable for urban areas with high-density use cases to provide the needed high data rate.

- **eSIM** - Using Embedded Subscriber Identity Module (eSIM) enables roaming capabilities and allows the EV charging station to use any mobile signal from any operator in the area. eSIM is essential as some areas could be supported by one mobile provider whereas other areas are not.
- **LPWAN:** LPWAN technologies like LTE-M and NB-IoT are 4G/5G-based solutions that can be considered for different classes of services as they could further improve the coverage and are ideal for some remote areas since they are delivered using lower frequency bands. LTE-M can offer more bandwidth than NB-IoT. It is good to keep in mind that the latest EV charging stations may require more throughput compared with the traditional ones. As more new messages and features require more data rates. This means that it is good to consider having more bandwidth for the EV charging station in the future to avoid any challenges in the operation.

Note that technologies like Wifi which operates in the unlicensed 2.4 and 5 GHz bands and EV charging-based are prone to interference which could compromise the security and privacy of the data exchange process. Wifi is not ideal for connecting EV charging stations (especially in rural and hard-to-reach areas) because of short-range coverage, and security vulnerabilities. The private and sensitive data collected by the EV charging networks need to be transmitted via a reliable and robust connectivity solution with security.

Satellite Communication

As shown in Figures 1-5, for remote locations such as some hard-to-reach areas in Moray and Western and Northern Scottish isles including Shetland where there is no mobile coverage at all from any mobile network provider, satellite systems could provide connectivity, but can be more expensive choice comparing with the public mobile and have higher latency. Satellite communication removes the geographical obstacle present in the Highland and Isles regions but the signal is susceptible to weather conditions and satellite visibility.

What are the impact of switching off the 3g network in remote and rural areas of Scotland?

EV charging systems require reliable and secure connectivity between the charging infrastructure and the central management system. The UK has set in motion the phasing out of 3G networks which will have significant implications for EV charging networks that have relied on 3G services. The option of transitioning to advanced networks is dependent on the location as smart charging functionality relies on connectivity to exchange EV charging information like the state of charge information, real-time remote diagnostics, the load and the tariff in order to calculate the cost of the charge and enable the payment capabilities offered via web Application Programming Interface (APIs) to the Central Management System (CMS).

The impacts on EV charging stations are listed below:

- For the EV charging infrastructure to be transitioned to advanced networks, the SIM cards currently in use have to be compatible with the 4G technology. 4G complaint hardware could mean zero-touch or a few configuration steps provisioning to 4G signal.
- If the connected EV charging station does not support 4G, the switch-off will affect such device which is currently working on 3G mobile connectivity services. In this case, there is a need to upgrade the devices to be capable of using 4G.
- 3G chargers could still charge the EV vehicle but some functionality may be lost depending on the vehicle type.
- Around 92 per cent of the UK has outdoor 4G coverage from at least one provider but this drops to 83 per cent in Scotland.
- EV charging station from 2G/3G to alternatives recommended in this report.

Although Ofcom has stated that minor disruption could affect some services, some expectations for MNOs (namely EE, Vodafone and O2 networks) have been set by Ofcom to ensure continuing the required services. These expectations include:

- Reducing coverage impact by upgrading existing 3G sites into 4G. As shutting down 3G will free up radio frequencies which can be used in faster 4G and 5G services
- Notifying the customers in advance of any changes (3-6 months advance notice)
- Share knowledge across the industry and increase awareness so the applicable suppliers have enough time to update their devices and avoid losing any critical services.

Not all EV charging stations will be affected by the 3G switch-off. Only legacy type of existing EV charging stations using 3G to communicate with the cloud or the grid will require upgrades in order to maintain the appropriate operation. Some existing legacy modems will have to be upgraded to work with 4G/LTE networks whereas other newer EV Charging stations already using the 4G/LTE will not be affected. The EV charging stations with embedded 3G models should be updated or replaced to support the new communication technology. So, the replacement of communications technology may require a modification or an update to the EV charging station and its communication router as well as its software.

What are the short/long-term communication solutions to be considered in the EV charging?

There are various communication technologies which can replace 3G services. Examples include 4G/5G and their variants LTE-M, NB-IoT and satellite communication. However, HITRANS must keep in mind that an alternative solution might not be straightforward even if they provide the correct characteristics to replace 3G. The 3G shutdown could disrupt EV charging data for some vehicles and chargers such as older EV chargers with 3G-only connectivity. These might lose features like remote monitoring, payment problems, receiving charging info or app-based controls (i.e., or even finding the charger on apps) in addition to system integration challenges.

Irrespective of whether the solution is long-term or short-term, it is not realistic to have a single wireless technology/provider serve every EV charging infrastructure in a given location for redundancy purposes. Wireless solutions to replace 3G must facilitate reliable data consumption and payment transactions. That is, establishing a reliable network connection between EV charging stations for data logging, access control and maintenance purposes.

Short-Term

Mobile (LTE/4G and 5G subject to availability in some rural areas): Widely available, and reliable for data transmission between chargers and the control and management system.

Use of mobile roaming SIM cards as they can keep the connection and may offer seamless connectivity across various mobile networks.

Satellite communication options: Broadband Global Area Network (BGAN) and Starlink. BGAN Satellite communication are technologies that provide global coverage and offer communication data services using BGAN modems that connect the BGAN networks with the EV charging station located in the hard-to-reach area (suitable to any location in Moray, Western and Northern Scottish isles including Shetland and Orkney). BGAN network is slower in speeds compared to Starlink, but is reliable and offers global coverage. Whereas, Starlink is a collection of low-earth orbit satellites that provide high-speed internet access via a fixed Starlink dish for connection. Starlink provides faster internet speeds compared to BGAN, but less coverage (coverage is still developing but Starlink has declared earlier this month that the Starlink coverage is now available in Scotland, namely in the mainland and Skye to the Outer Hebrides, Scrubstar to the Orkney Islands). The Starlink's coverage, speeds, and latency can be checked in Scotland using their availability map (i.e., https://www.starlink.com/map).

As can be seen in Figure 12, Starlink has expanded its coverage to include the Moray and Western and Northern Scottish isles including Shetland and the installation services for Starlink are available in Scotland through trusted engineers and experts. Therefore, Starlink's coverage does indeed cover the entirety of Scotland.

Figure 12 Starlink coverage in the highland and the Scottish Isles (https://www.starlink.com/map)

Choosing between BGAN and Starlink depends on the requirements and the end application. BGAN is the right choice for portable and global coverage whereas, Starlink could be the choice if the coverage is available due to the high internet speed if needed. In EV no need for high internet speed so the right option can be the availability and the associated costs. BGAN is ideal for occasional use due to per-MB cost and Starlink is better for consistent internet access with a predictable monthly cost. Starlink offers several different packages that range from £75 per month without the cost of the dish (about 460 GBP), see figure 13.

BGAN M2M Service Plans and Pricing

£ GBP Pricing | $ USD Pricing

Plan:	1 MB	2 MB	5 MB	10 MB	15 MB	20 MB
Price Per Month:	£20.00	£26.00	£39.00	£65.00	£87.00	£98.00
Included Data:	1 MB	2 MB	5 MB	10 MB	15 MB	20 MB
Activation Fee:	£26.00	£26.00	£26.00	£26.00	£26.00	£26.00
Overage Fee Per MB:	£19.60	£13.00	£12.20	£10.40	£9.60	£8.70
Minimum Contract Term:	1 Month	1 Month	1 Month	1 Month	1 Month	1 Month
Early Termination Fee:	None	None	None	None	None	None
SKU:	AT-BGANM2M-1MB-22-1	AT-BGANM2M-2MB-22-1	AT-BGANM2M-5MB-22-1	AT-BGANM2M-10MB-22-1	AT-BGANM2M-15MB-22-1	AT-BGANM2M-20MB-22-1

Figure 13 BGAN M2M Service Plans and Pricing

Long-Term

- Private LTE/4G/5G network that could provide good coverage and scalability (to the hard-to-reach areas) for current and future demands. LTE/4G/5G cellular is the best alternative for long-term stationary/mobility communication in EV charging infrastructure for EV energy demand/supply management, resource allocation, etc. Among the different radio access technologies considered, 4G-LTE cellular offers the advantages of the widest coverage and high quality of service that could enable EV charging infrastructure providers to be deployed in remote and rural locations. 5G when deployed in the lower sub-GHz band offers improved performance., i.e. ultra-low latency, high reliability, and high mobility support. The eSIM technology prevents vendor lock-in and allows EV charging infrastructure to automatically connect to the best available network.
- NB-IoT/LTE-M are two lower data rate components of 4G/5G technology with improved range and coverage in rural and hard-to-reach areas that could be leveraged to scale EV charging deployment.
- Broadband over Power Line (BPL): runs over existing power lines for communications.
- UHF radio technology can be a proper communication solution for EV charging needs, benefiting from its frequency range and penetration capabilities.

CONCLUSIONS AND RECOMMENDATIONS

Connectivity is crucial to authenticate EV users and enable payments. Keeping EV chargers fully functional and up to date is a necessity to support the deployment of the EV and its transition. Key recommendations of what can be done to ensure the reliable connectivity of the EV charging stations in Moray and Western and Northern Scottish Isles including Shetland are listed below:

- Legacy charging stations from various EV charging manufacturers which use 3G networks for their connectivity might be affected by the 3G shutdown.

- Although some chargers can be configured without communications networks and may still be able to charge the vehicle, some key functionality such as calculating power consumption and payment will be lost.
- 3G-to-4G modem upgrades are needed to all legacy charging stations that rely on 3G connectivity in Moray, Western and Northern Scottish Isles including Shetland and Orkney.
- Open Charge Point Protocol (OCPP) can be used as a tool to monitor EV charging stations and detect any network failure and malfunction at the charger/network level.
- Use multi-network (roaming) 4G SIMs to maximise connectivity in rural and hard-to-reach areas.
- Satellite communications such as BGAN and Starlink can be an option which could guarantee the connectivity of the EV charging point, however, the cost to enable that could be considered.
- UHF radio technology and BPL can also be considered as proper communication solutions for EV charging needs in hard-to-reach areas.

Note: Swarco and Siemens charging stations are the key manufacturers which are in use in the Islands and Orkney and rely on 3G connectivity. The communication models for some versions of Swarco charring stations are via Ethernet port (by default) or 3G/GPRS modem (optional). If the charging station is connected via the 3G/GPRS modem, then the modem should be updated as some Swarco charging stations are ONLY support 3G/GPRS connectivity. In addition to that, for remote management Swarco charging stations which use 3G for remote management of the chargers, like checking status and receiving alerts may not directly impact charging functionality, but could make it harder to maintain the chargers and support payment. Similar to Swarco, Siemens with only 3G mobile modem will not work properly and require a new modem which can support the new technology (i.e. 4G/LTE). For all Siemens and Swarco chargers that are built-in 3G communication, the 3G shutdown could impact EV chargers if they communication models have not been updated to support the new 4G technology.

Updating the connectivity of Swarco/Siemens legacy EV charging stations depends on the model and its available capability and existing feature. Upgrading the mobile connectivity module can be an option for some models, whereas, some other models may not be upgradable. Depending in the age and the model and its functionality, replacing it with a newer model with built-in connectivity features might be the most practical solution (this option is available for some legacy Siemens charging stations).

These are just some of the options to consider. The best solution will depend on various factors like existing infrastructure, budget, and future scalability needs.

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APPENDIX -

Use Cases

- **Chargepoint** (i.e., Europe’s famous smart charging infrastructure) shared a message with the public stating that a modem upgrade was required due to the shutdown of the 3G service in the area. Chargepoint declared on 31 of Jan 2022 that they are creating a special modem upgrade kit which enables the EV chargers to switch from 3G to 4G in minutes. The statement also indicated that the charging station will lose connectivity if the modem upgrade has not been performed and the charging station will be offline. It might be able to charge but no payment data and charging sessions will be available.

- **EV chargers'** key providers such as Tesla, Subaru, Mojio and GM are introducing 3G-to-4G modem upgrades to their customers which even could provide some enhanced functionality https://guidehouseinsights.com/news-and-views/as-3g-hits-end-of-life-cars-and-ev-chargers-need-upgrades. Moreover, JuiceBar in the USA offered its 'Trade Up Program' to owners of affected 3G-connected chargers (i.e., JuiceBar's connectivity via 4G LTE CatM1 charger)https://www.globenewswire.com/en/news-release/2022/02/03/2378340/0/en/Chaos-with-Commercial-EV-Charging-Infrastructure-as-3G-Shutdown-Begins-this-Month.html.

Mobile coverage map

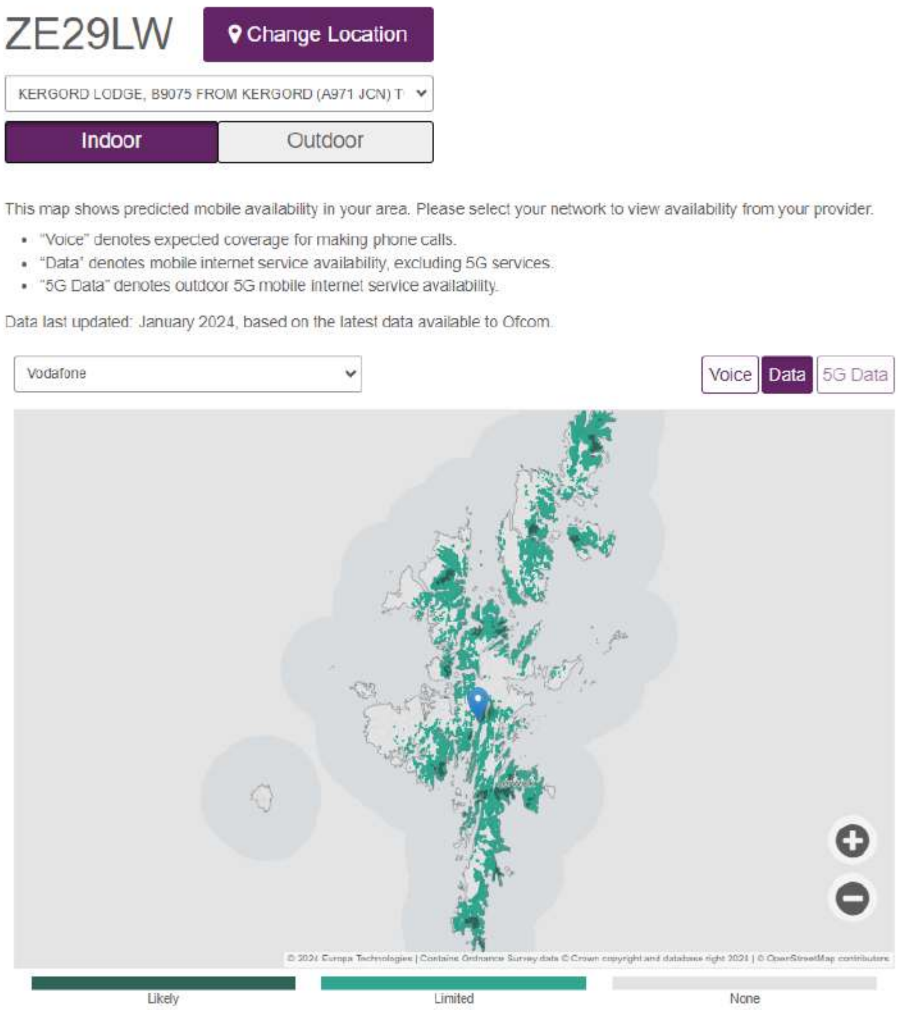


Figure 14 Vodafone mobile coverage map and signal availability in the Shetland- Jan 2024 (source-Ofcom)

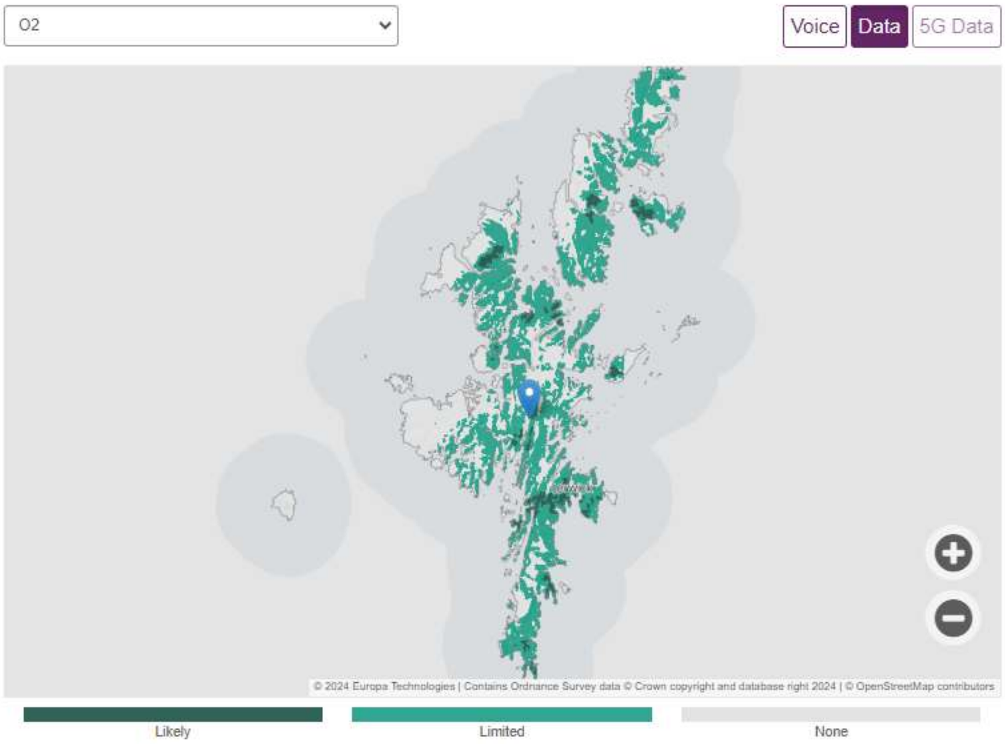


Figure 15 O2 mobile coverage map and signal availability in the Shetland- Jan 2024 (source-Ofcom)

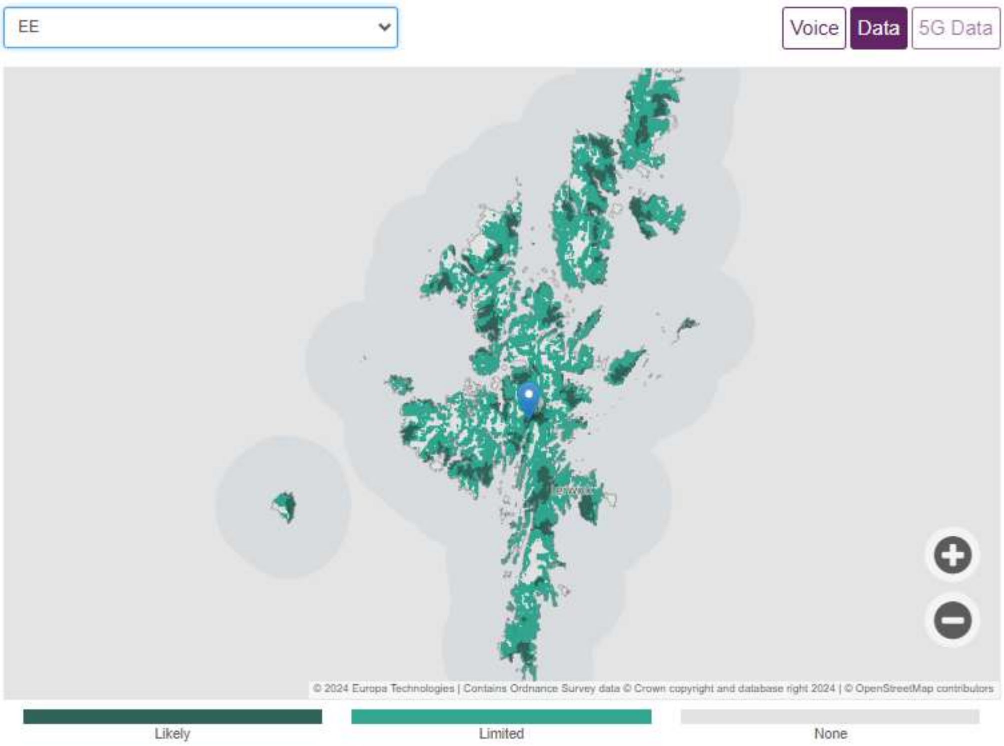


Figure 16 EE mobile coverage map and signal availability in the Shetland- Jan 2024 (source-Ofcom)

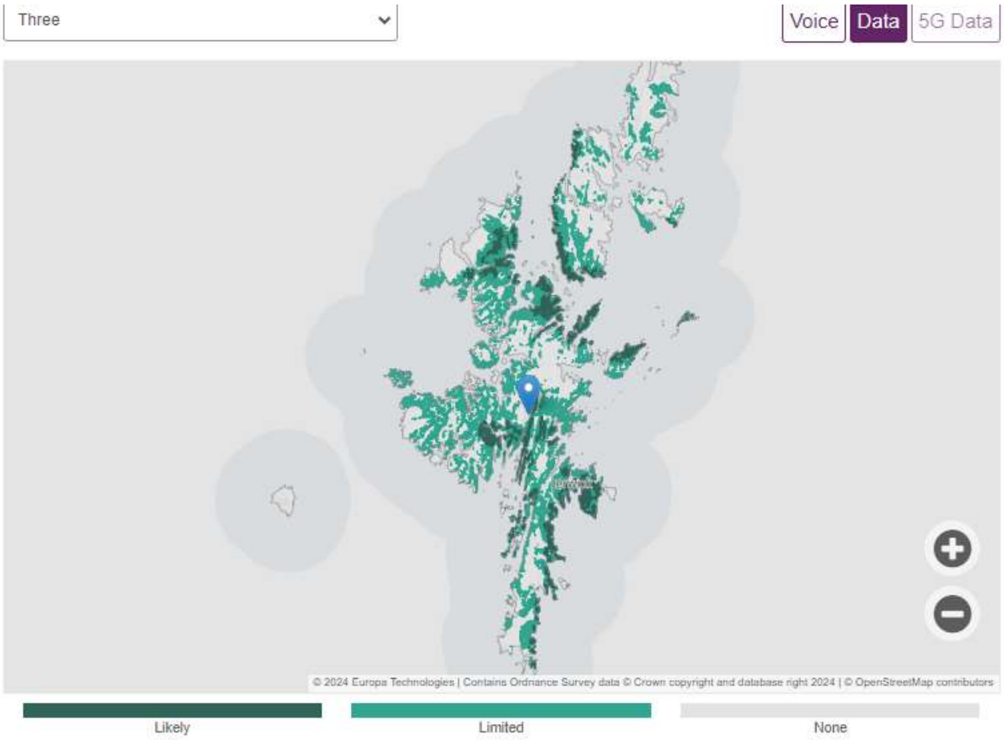


Figure 17 Three mobile coverage map and signal availability in the Shetland- Jan 2024 (source-Ofcom)

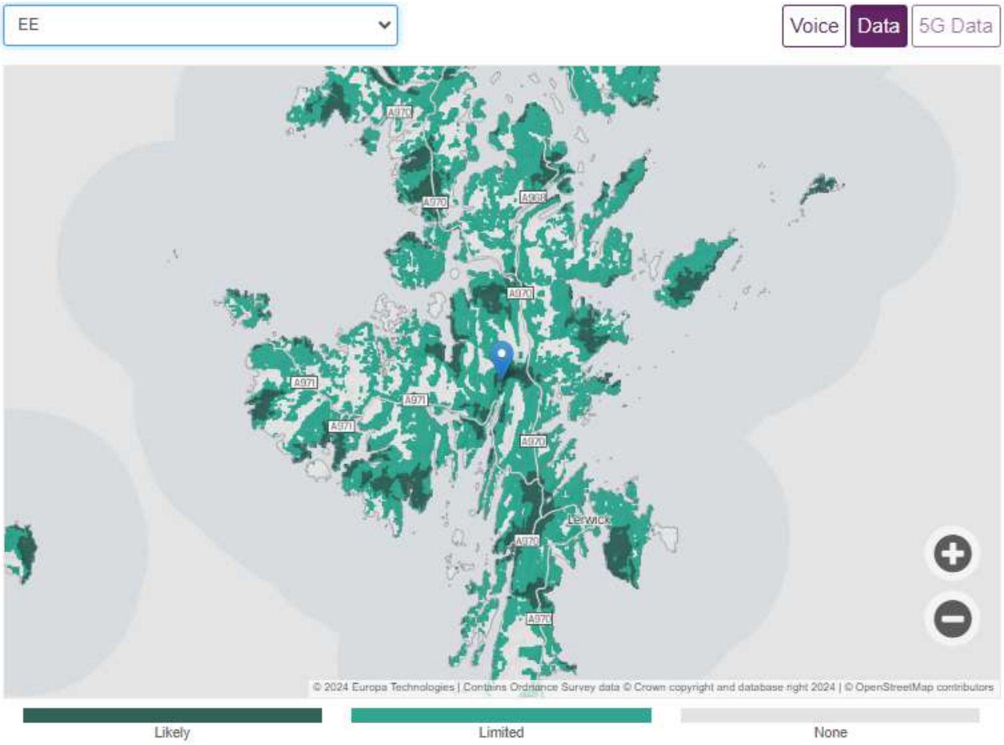


Figure 18 EE mobile coverage map and signal availability in the Lewis and Harris- Jan 2024 (source-Ofcom)

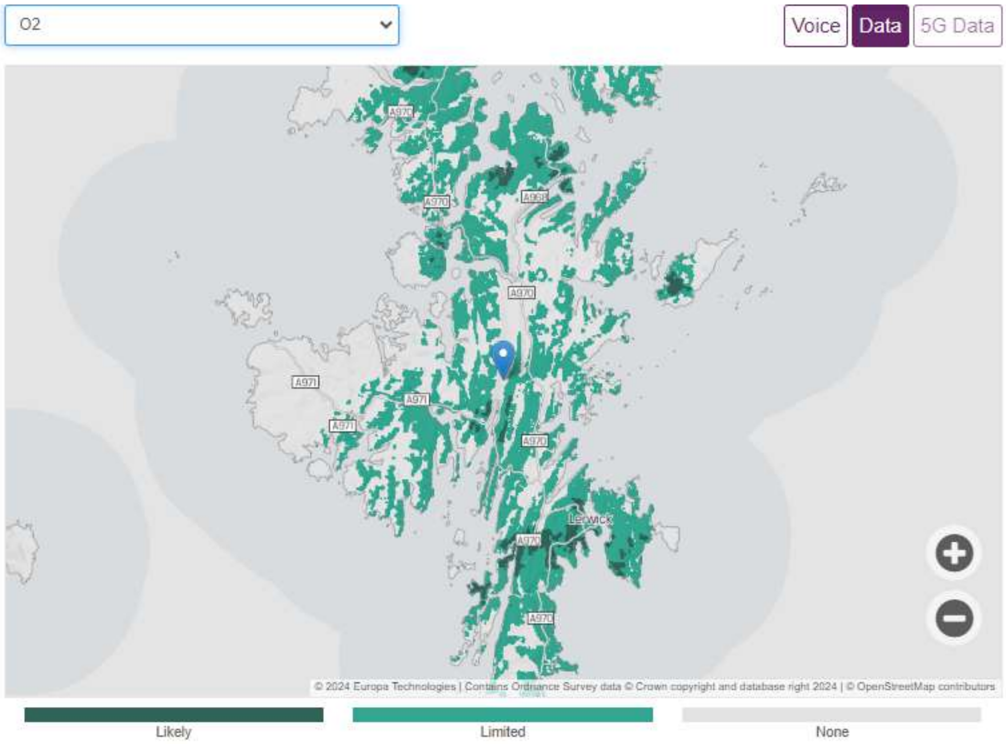


Figure 19 O2 mobile coverage map and signal availability in the Lewis and Harris- Jan 2024 (source-Ofcom)

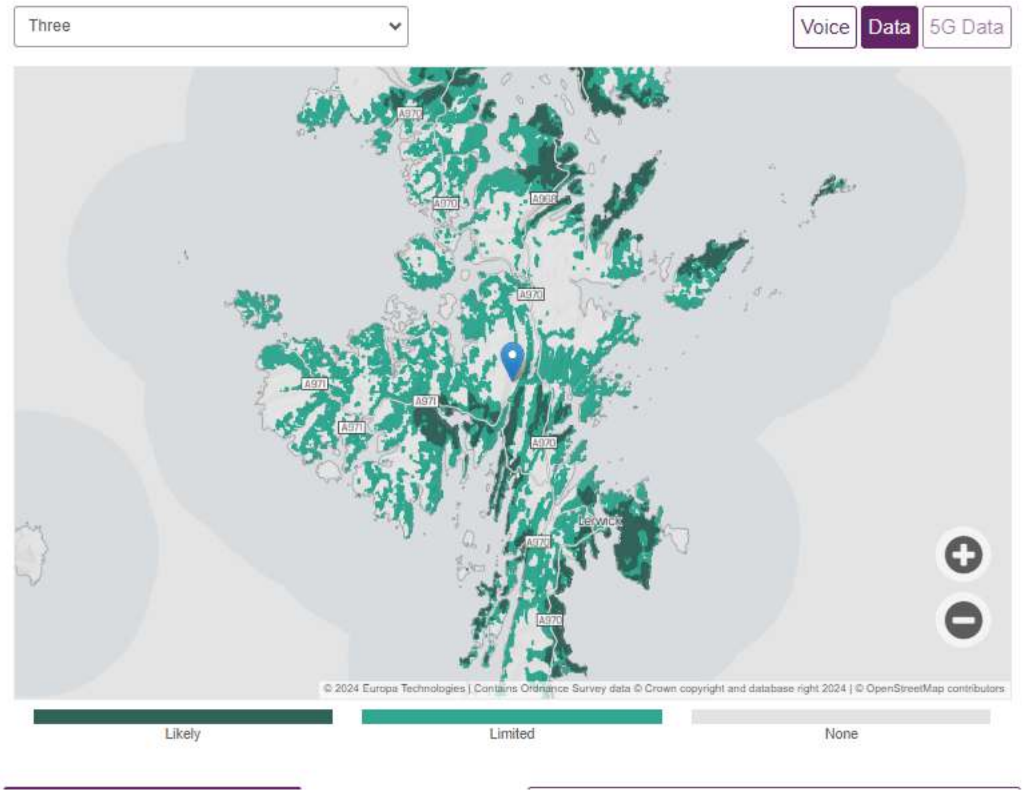


Figure 20 Three mobile coverage map and signal availability in the Lewis and Harris- Jan 2024 (source-Ofcom)

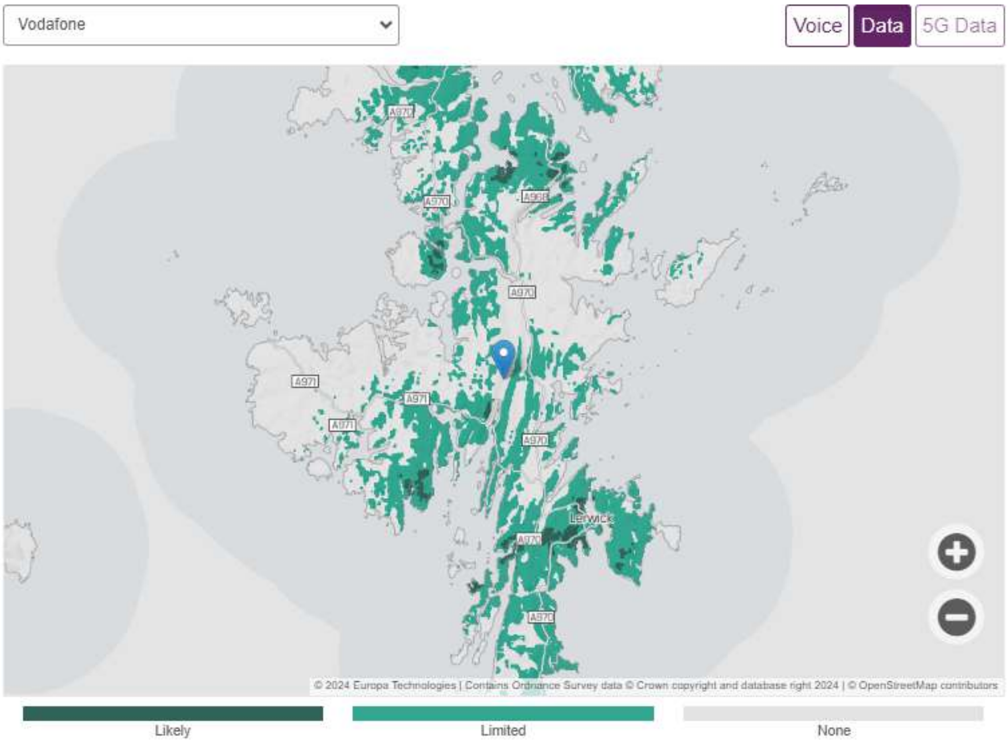
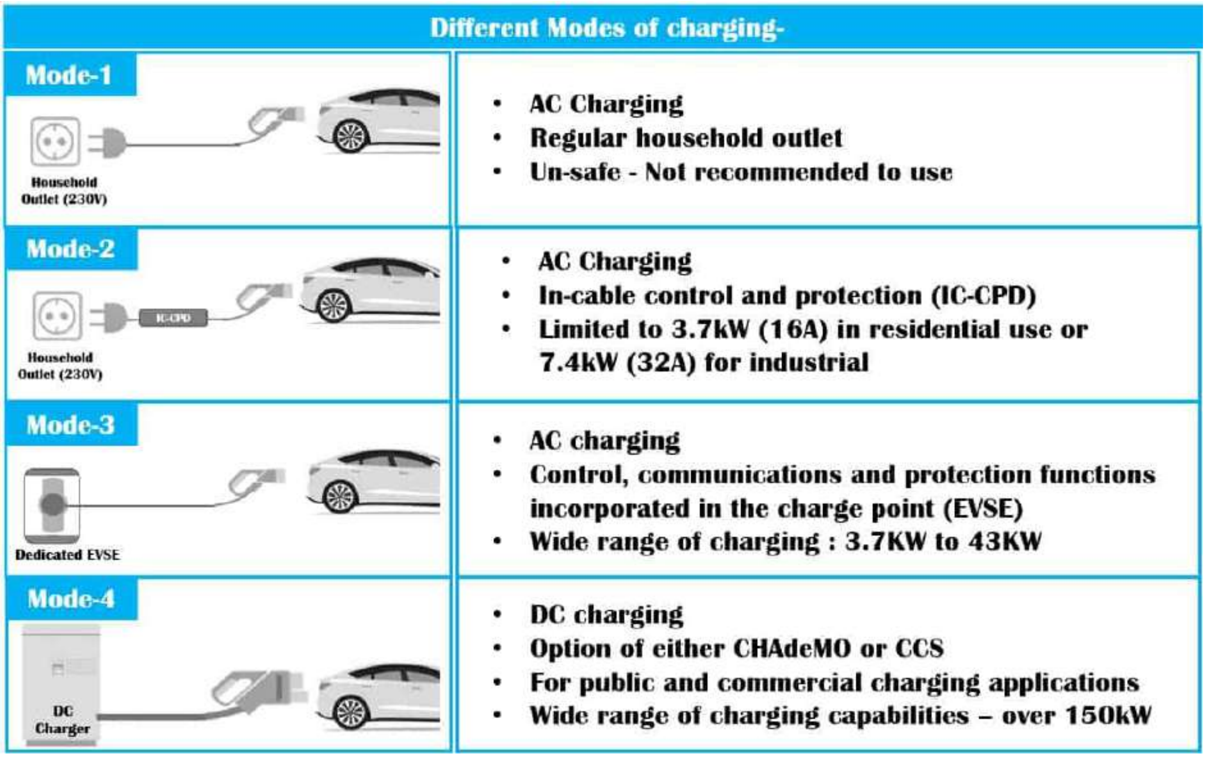


Figure 21 Vodafone mobile coverage map and signal availability in the Lewis and Harris- Jan 2024 (source-Ofcom)

EV Charger Levels



Different Modes of charging-	
Mode-1 Household Outlet (230V)	• AC Charging • Regular household outlet • Un-safe - Not recommended to use
Mode-2 IC-CPD Household Outlet (230V)	• AC Charging • In-cable control and protection (IC-CPD) • Limited to 3.7kW (16A) in residential use or 7.4kW (32A) for industrial
Mode-3 Dedicated EVSE	• AC charging • Control, communications and protection functions incorporated in the charge point (EVSE) • Wide range of charging : 3.7KW to 43KW
Mode-4 DC Charger	• DC charging • Option of either CHAdeMO or CCS • For public and commercial charging applications • Wide range of charging capabilities – over 150kW

Figure 22 Various "charging modes"