Evaluation of 4G and Full Fibre Coverage in the UK: A Five-Year Analysis

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1. Executive Summary

The availability and adoption of 4G mobile and Full Fibre coverage in the UK are crucial, prompting the UK government to plan widespread promotion of these technologies. This study aims to understand their evolution, addressing two key questions:

1. How advanced is 4G coverage in the UK over the past five years in terms of nations and local authorities?

2. Are there any notable associations between the usage rates of 4G and Full Fibre connectivity in the UK, categorised by nations and local authorities?

Two datasets were analysed: one detailing mobile coverage, including 4G, and the other detailing fixed coverage, including Full Fibre. GeoJSON data were also included for national-level analysis of the UK. Techniques included line graphs, bar graphs, and K-means clustering to visualize and categorise connectivity levels.

Over the past five years, 4G availability in the UK improved significantly, meeting government targets. England consistently maintained high availability, reaching 86.37% by 2023, while Scotland saw a notable increase of 10.57%. However, urban areas generally had better coverage compared to rural regions, highlighting an urban-rural disparity, especially in England. Cities like Carlisle and Glasgow showed significant increases, while areas like the Orkney Islands and Harrow experienced declines by 2023. Future efforts should concentrate on enhancing coverage in declining and rural areas, as cities have already achieved high levels of coverage, aligning with government objectives. Additionally, averaging 4G data before analysis may have obscured local differences and reduced precision, indicating a need for reassessment.

Over the last five years, 4G and Full Fibre coverage have steadily increased, with all nations maintaining high 4G availability, surpassing 60%. Notably, Northern Ireland stood out for its remarkable growth in Full Fibre coverage, exceeding 4G availability by 2022 and reaching

nearly 90% by 2023. In 2023, major cities showed higher availability of both 4G and Full Fibre, while rural areas lagged behind, echoing previous trends. England exhibited a clear rural-urban divide in connectivity for both 4G and Full Fibre, with Northern Ireland excelling in overall connectivity despite lower 4G coverage due to robust Full Fibre availability. This outcome was influenced by the use of K-means clustering, suggesting potential for reconsideration, particularly in Northern Ireland. England and Wales demonstrated varied coverage groups, while Scotland fell behind, indicating a need for prioritising connectivity improvements.

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2. Aims and Objectives

This study aims to understand the availability of 4G mobile coverage and Full Fibre coverage in the UK, as well as how the adoption of both 4G and Full Fibre coverage has changed over the last five years. It combines two datasets: one containing information about mobile coverage, including 4G, and the other containing information about fixed coverage, including Full Fibre. Both datasets provide data at the local authority level in the UK. Additionally, GeoJSON data are used to analyse at the UK national level.

There are two questions for this study: how advanced is 4G coverage in the UK over the past five years in terms of nations and local authorities? And are there any notable associations between the usage rates of 4G and Full Fibre connectivity in the UK, categorised by nations and local authorities?

3. Background

4G coverage remains the foundation of mobile services and continues to handle the majority of mobile data traffic (techUK, 2023). In addition, the government has promoted 4G, targeting 95% coverage by 2025 under the Shared Rural Network (SRN) agreement (Clark and Baker, 2024).

Full Fibre is in high demand due to its enhanced speed, which is expected to meet the internet needs of homes and offices for decades to come (Beckett, 2024). The UK government, viewing the rollout of Full Fibre as crucial for achieving nationwide economic growth, has undertaken efforts to promote it (O'Halloran, 2022).

Given that both 4G and Full Fibre are considered crucial broadband connectivity technologies promoted by the government, researching their advancement across the UK holds significant value. It offers insights into how the UK's networking technology plans have evolved and provides valuable perspectives on areas needing improvement for the future.

4. Scope and Sources of Data

4G and Full Fibre datasets used for this investigation are available from 'Connected Nations and infrastructure reports', hosted on Ofcom. GeoJSON data is available from 'Local Authority Districts (December 2022) Boundaries UK BUC', hosted on Office for National Statistics. All data are under the Open Government Licence v3.0, which states that I am free to:

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provided that I

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All the work in this report is allowed under this licence. Further details and links are given in Appendix 2.

4.1 4G coverage data

This dataset shows the percentages of 4G availability for each local authority from 2019 to 2023. It includes detailed information on 4G availability in various contexts, such as indoor, outdoor, and motorway areas. Additionally, the dataset provides availability percentages based on the number of operators and regions.

Not only must the data be consistent from 2019 to 2023, but it also has to contain enough information for analysis. Therefore, 4G availability data for all operators was extracted, as it provides sufficient coverage for all areas across the UK.

4.2 Full Fibre coverage data

The dataset includes the number of premises using Full Fibre services as well as the percentage of its availability in each area. Since the 4G data deals with percentages of availability, the percentage data for Full Fibre was chosen to facilitate comparison and analysis with the 4G data. This dataset includes the percentages of availability for each local authority from 2019 to 2023.

4.3 Information about nations

This study aimed to analyse network technology not only at the local authority level but also at the national level, using both 4G and Full Fibre data. Therefore, GeoJSON data used in the TMA02 stage was adopted to identify which nation each local authority belongs to.

4.4 The Combination of Datasets

Combining 4G, Full Fibre, and GeoJSON datasets offers a detailed understanding of the UK's digital infrastructure, enhancing strategic planning and policy development for more equitable network coverage. This combination is highly impactful, providing essential insights to improve digital connectivity across the UK.

5. The Analysis Pipeline

5.1 Question 1: 4G advancement analysis

Since the 4G dataset was investigated in TMA02, the first stage involved extracting data for all locations with available operators, including columns such as 'premises (indoor)', 'premises (outdoor)', 'geographic (outdoor)', 'A and B roads', and 'motorways'. Due to the complexity and workload associated with analysing multiple columns, it was necessary to simplify the data. Therefore, to facilitate comparison across areas, values for each location were averaged and grouped by local authority. However, it is important to note that this averaging process may obscure local variations and reduce precision, thereby influencing the effectiveness of data analysis, data quality, and the reliability of the results (Pannell, 2023).

In addition, for effective comparative analysis between nations, the GeoJSON data was employed to append the relevant national information to each local area. This integration ensured that every local area was appropriately tagged with its corresponding nation, facilitating a robust examination of inter-country differences and patterns.

The initial analysis illustrated the five-year progression of 4G across each nation using a line graph. Following this, a bar graph depicted the percentage increase by nation. For the UK's current status, data from 2023 were divided into four groups (very high, high, medium, low) based on percentile statistics and visualised on a map. The analysis concluded by identifying local authorities experiencing notable increases or decreases in 4G coverage over the five-year period.

5.2 Question 2: 4G and Full Fibre connectivity analysis

Datasets relevant to Question 2 were partly prepared during the analysis for Question 1. The necessary 4G data was imported from Question 1, while Full Fibre data from 2023 came directly from the source. For the five-year analysis, Full Fibre data were imported from

MongoDB, where they had been cleaned and investigated at the stage of TMA02. GeoJSON data were used to append national information to each local area, mirroring the approach for 4G data.

A scatter plot was created to depict the relationship between 4G and Full Fibre connectivity. K-means clustering techniques were then applied to segment the scatter plot into three groups. Goswami and Chakrabarti (2012) state that the quartile clustering technique, in particular, could offer more insightful clustering. Therefore, percentile statistics (25th, 50th, and 75th) were used to determine centroid points for clustering. Each marker was assigned to the nearest centroid, resulting in three groups: high (121 markers), medium (120 markers), and low (132 markers), as illustrated in Figure 1. It's imperative to acknowledge that alterations in centroid values can markedly influence both segmentation and subsequent analysis outcomes.

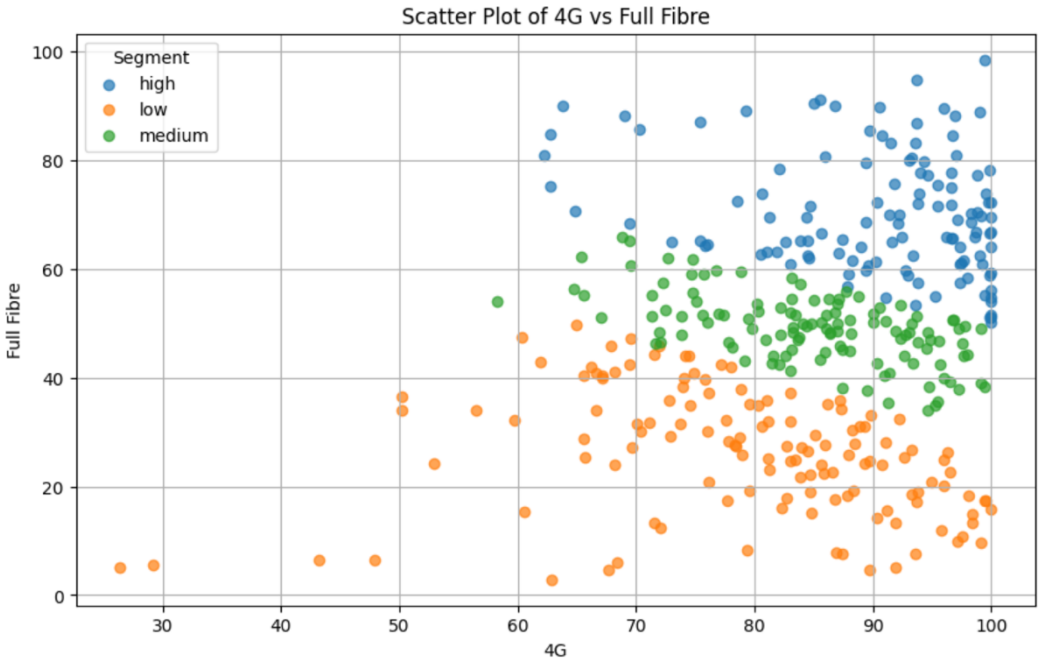

Figure 1

The segmentation was visualised on a map to observe the discrepancy in 4G and Full Fibre connectivity in 2023. Furthermore, patterns in the association between 4G and Full Fibre across nations were explored through a scatter plot with nation labels. Finally, a five-year analysis of connectivity advancements by nation was undertaken, depicted via a line graph to identify significant correlations in 4G and Full Fibre usage rates in the UK.

6. Findings

6.1 Question 1: 4G advancement analysis

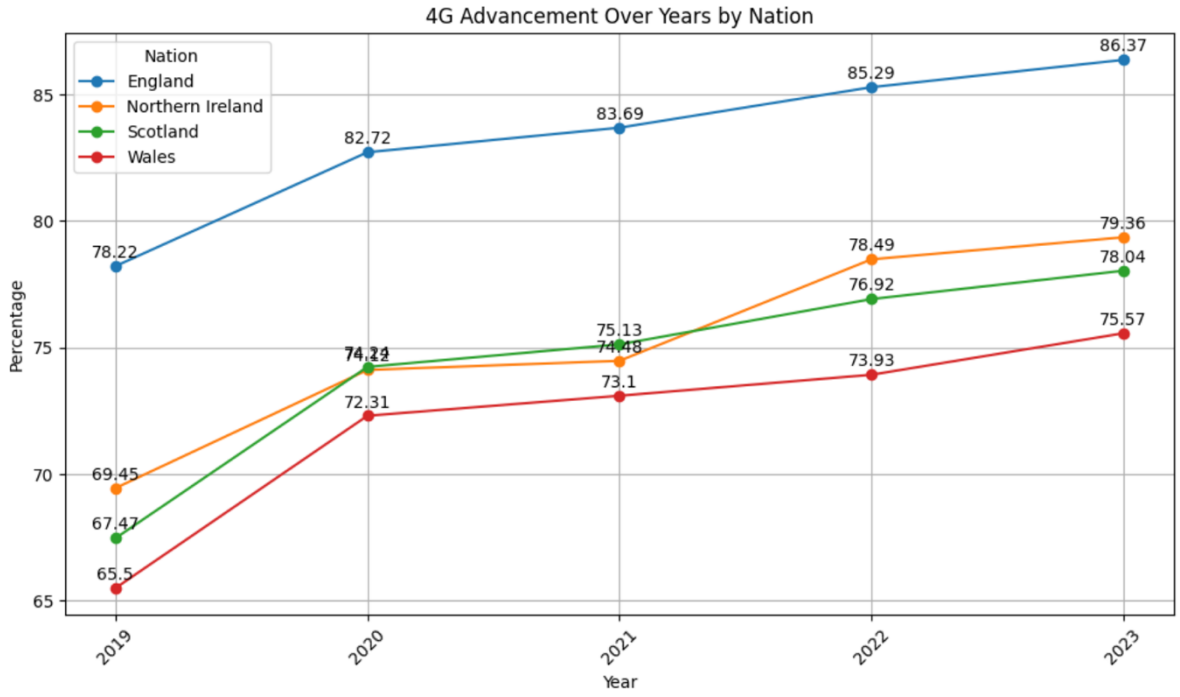

Figure 2: 4G Advancement over Years by Nation

Figure 2 demonstrates the improvement in 4G availability across each nation in the UK from 2019 to 2023. Among the nations, 4G coverage increased the most in England, reaching an average of over 85% in 2023. Northern Ireland also showed significant improvement, starting at less than 70% and reaching nearly 80% in 2023. Scotland experienced a similar trend to Northern Ireland, even surpassing it between 2020 and 2021. Wales saw a notable increase in coverage from 2019 to 2020 (65.45% to 72.31%), with a gradual increase thereafter, reaching 75.57% in 2023.

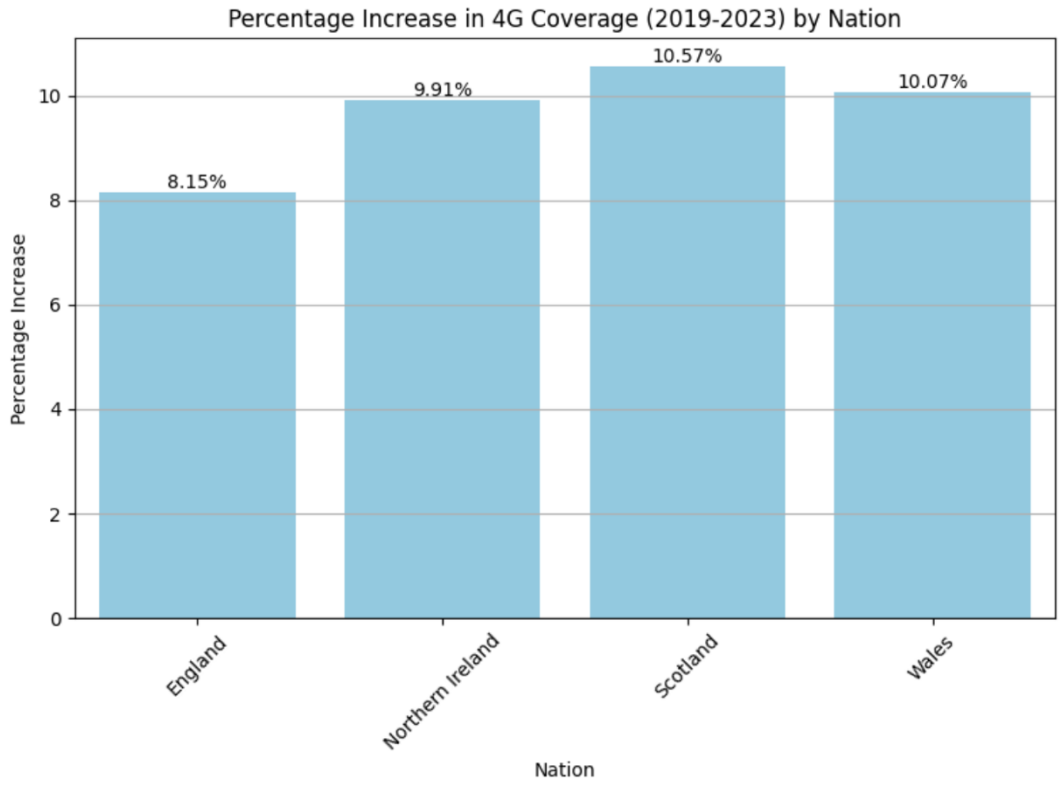

Figure 3: Percentage Increase in 4G Coverage (2019 -2023) by Nation

Although England maintained the highest 4G availability over the five-year period in the UK, Scotland experienced the greatest percentage increase with a 10.57% rise in 4G coverage between 2019 and 2023 (Figure 3).

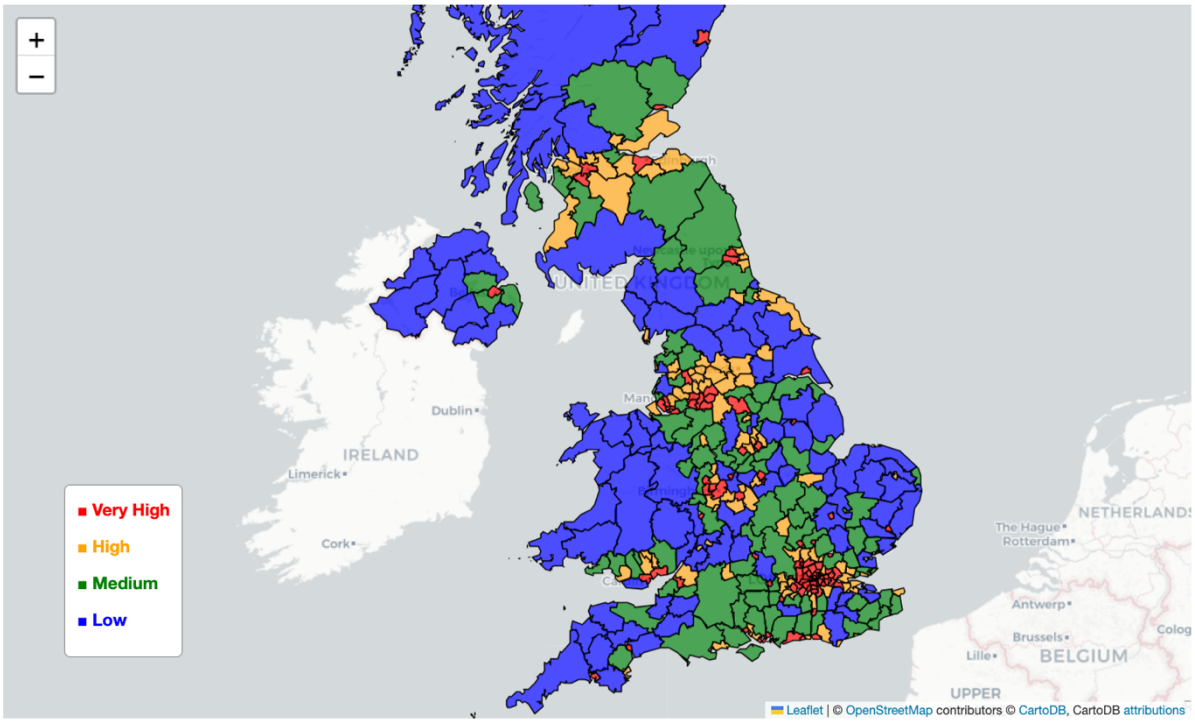

Figure 4: UK 4G performance in 2023

This map (Figure 4) shows the UK 4G performance in 2023 divided into four groups: Very High, High, Medium, and Low. It is clear that the capitals of nations and large cities such as London, Edinburgh, Manchester, and Birmingham had very high 4G performance. In contrast, rural areas had very low performance. However, 4G coverage was comparatively well spread (Medium) in southern England and some parts of northern England. High-performance areas are seen surrounding big cities (Very High) as well as in some parts of north-eastern England.

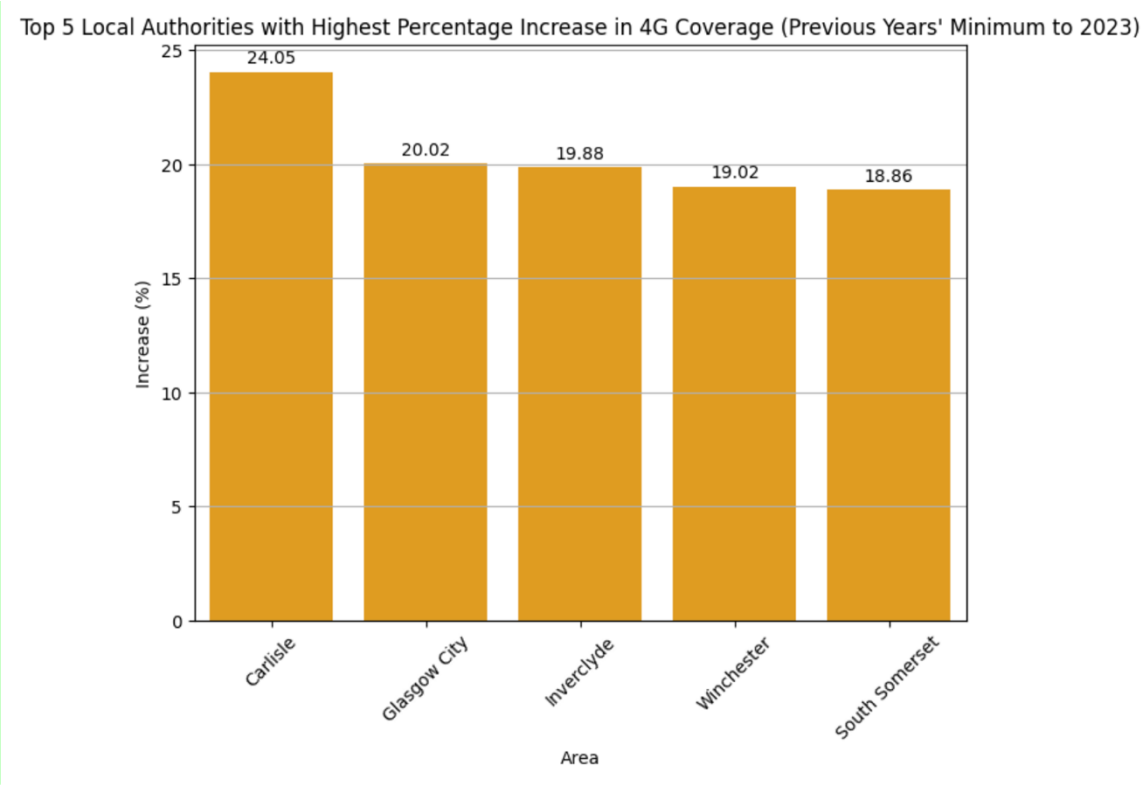

Figure 5: Bar graph of top 5 local authorities with highest percentage increase in 4G coverage

local authority	nation	year of min percentages	min (%)	percentages in 2023 (%)	increase (%)
Carlisle	England	2019	53.66	77.71	24.05
Glasgow City	Scotland	2019	77.65	97.67	20.02
Inverclyde	Scotland	2019	68.48	88.36	19.88
Winchester	England	2019	66.8	85.82	19.02
South Somerset	England	2019	61.49	80.35	18.86

Table 1: Table of top 5 local authorities with highest percentage increase in 4G coverage

Figure 5 and Table 1 show the top 5 local authorities with the highest percentage increase in 4G coverage from their minimum value in the previous years to the value in 2023. Carlisle experienced a significant increase in 4G coverage, with the coverage percentage rising from 53.66% in 2022 to 77.71% in 2023. This represents a percentage increase of 24.05%, the highest among the listed local authorities. Notably, the relatively large city of Glasgow also had a high increase with coverage rising from 77.65% in 2022 to 97.67% in 2023, resulting in a percentage increase of 20.02%.

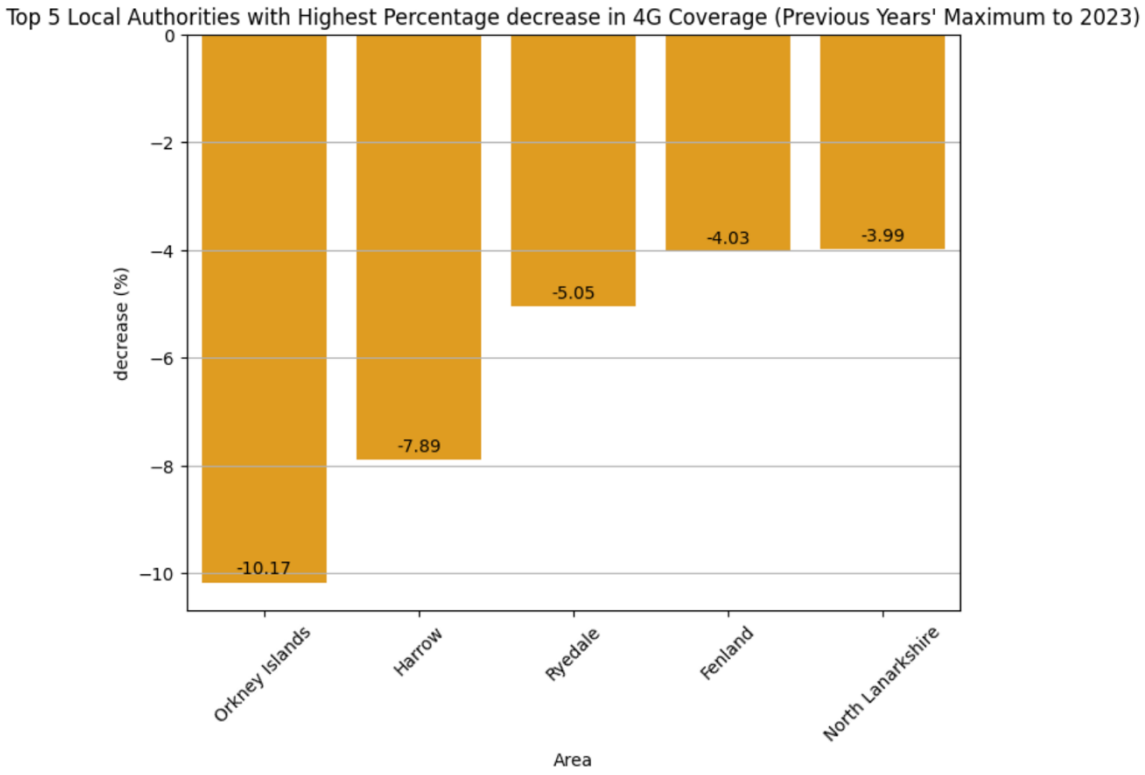

Figure 6: Bar graph of top 5 local authorities with highest percentage decrease in 4G coverage

local authority	nation	year of max percentages	max (%)	percentages in 2023 (%)	decrease (%)
Orkney Islands	Scotland	2021	36.52	26.35	-10.17
Harrow	England	2019	97.57	89.68	-7.89
Ryedale	England	2021	71.62	66.57	-5.05
Fenland	England	2021	76.24	72.21	-4.03
North Lanarkshire	Scotland	2019	92.25	88.26	-3.99

Table 2: Table of top 5 local authorities with highest percentage decrease in 4G coverage

Figure 6 and Table 2 show the top 5 local authorities with the highest percentage decrease in 4G coverage from their maximum value in the previous years to the value in 2023. Orkney Islands saw the most significant decrease, with a maximum 4G coverage of 36.52% in 2021, dropping to 26.35% in 2023, resulting in a percentage decrease of -10.17%. This indicates a substantial reduction in 4G coverage over the past two years. Three areas (Harrow, Ryedale, and Fenland) from England were ranked in the Top 5.

6.2 Question 2: 4G and Full Fibre connectivity analysis

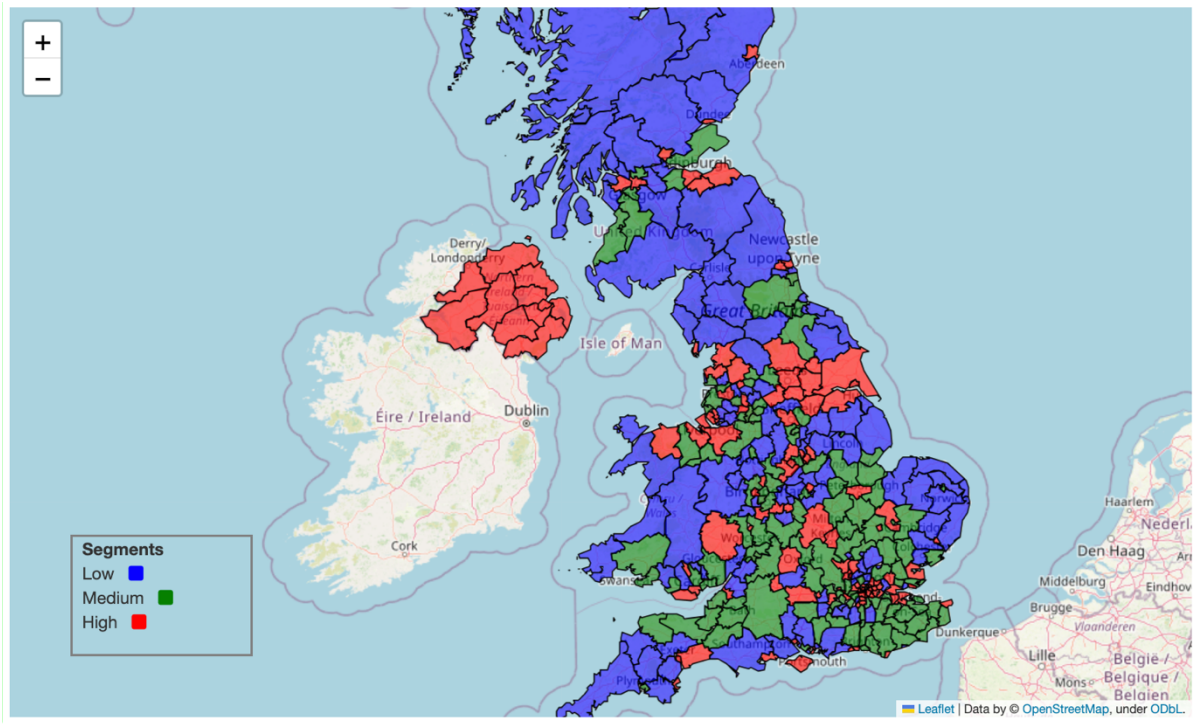

Figure 7: the map of the connectivity between 4G and Full Fibre in 2023

The map (Figure 7) illustrates the connectivity between 4G and Full Fibre in 2023, categorised into three distinct groups: High, Medium, and Low. The 'High' group signifies areas with abundant availability of both 4G and Full Fibre, while the 'Low' group indicates regions with limited accessibility to both technologies. The 'Medium' group represents moderate availability of both technologies.

Notably, Northern Ireland emerged as a key contributor to the advancement of 4G and Full Fibre networks, with all its areas classified as highly advanced. Similarly, regions with major urban centres, such as London, showcased exceptional performance in both connectivity domains. In contrast, Scotland exhibited comparatively lower performance in these advancements. Additionally, it is notable that the south side of England had more areas categorised as Medium.

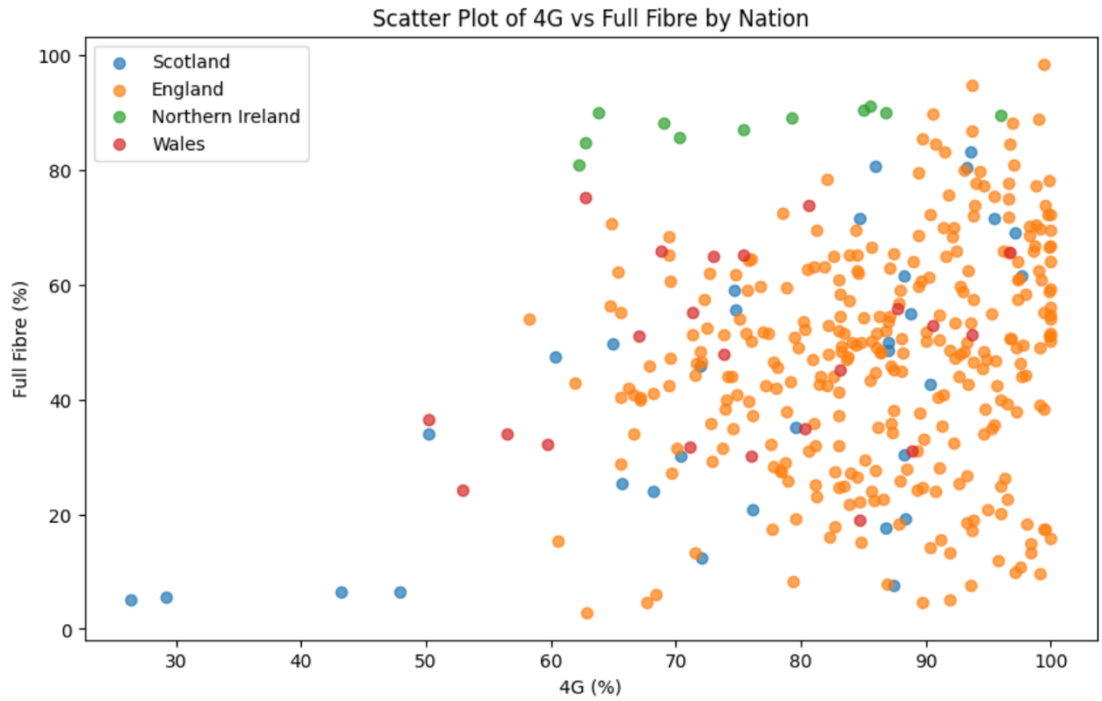

Figure 8: Scatter plot of 4G and Full Fibre by nation in 2023

In Figure 8, it is noticeable that all areas of Northern Ireland had high performance in full-fibre connectivity, with varying levels of 4G advancement. In contrast, some areas of Scotland showed significantly lower performance in both full-fibre and 4G. In England and Wales, 4G coverage was relatively high (over 60%), but full-fibre availability varies widely, ranging from 0 to 100%.

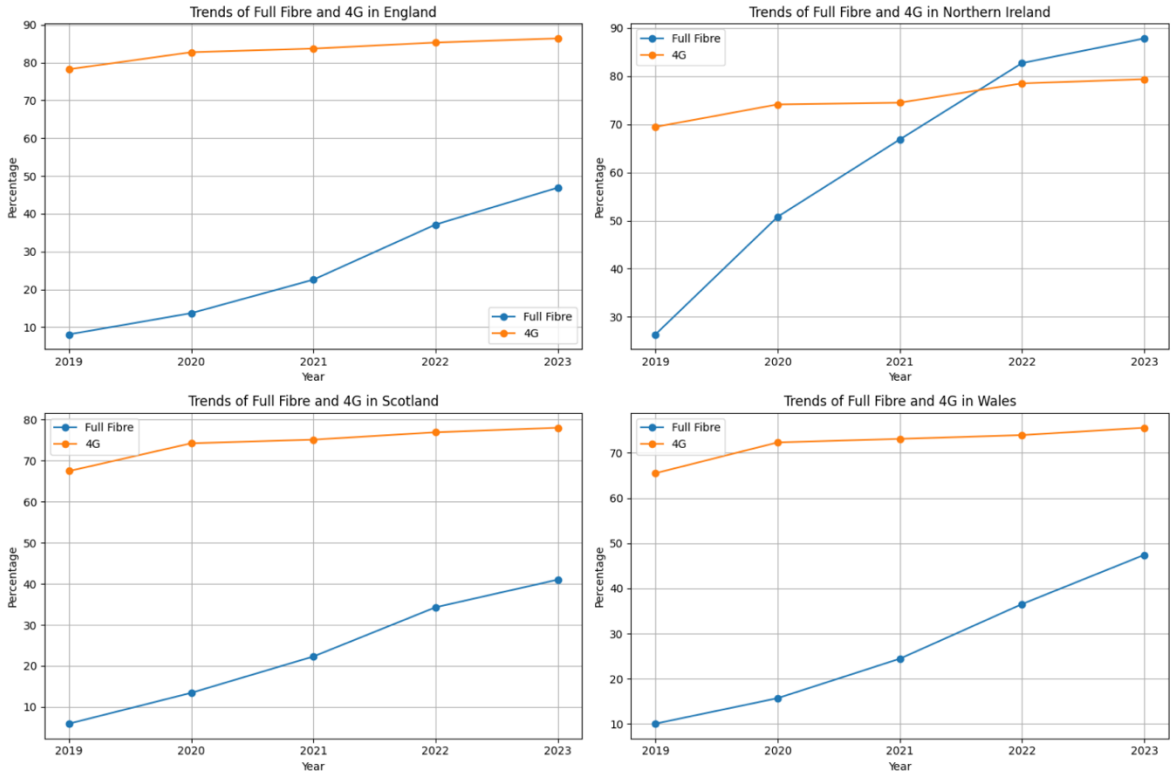

Figure 9: Trends of Full Fibre and 4G by nation

Examining the trends of Full Fibre and 4G by nation over a five-year period (Figure 9), similar patterns across all nations were observed, except for Northern Ireland. Throughout the period, 4G availability consistently exceeded 65%, with a gradual increase each year.

In contrast, Northern Ireland experienced a remarkable surge in Full Fibre availability, surpassing 4G percentages in 2022 and nearly reaching 90% by 2023. However, other nations saw slower growth in Full Fibre adoption, starting at around 10% in 2019 and not reaching 50% by 2023.

7. Conclusions and Recommendations

7.1 4G advancement in the UK

4G availability has improved over the past five years as planned by the government. England consistently maintained high availability, starting at 78.22% and rising to 86.37%. Scotland saw the most significant increase, with a 10.57% rise.

At the local authority level, larger cities tended to have higher 4G availability, while areas further from cities and closer to rural regions had weaker coverage. In England, this trend was evident. Carlisle and Glasgow experienced over a 20% increase in 4G coverage, whereas

the Orkney Islands and Harrow saw a decrease by 2023. Harrow's decline was notable as it was part of Greater London, contradicting the general trend. Further research is needed to determine if this was a temporary issue.

As the government aims for 95% 4G availability by 2025, efforts should focus on improving coverage in areas with declines and in rural regions. Larger cities have already achieved high 4G availability.

The 4G data were averaged before analysis, which may have obscured local variations and reduced overall precision. Recognising these limitations is crucial for accurate interpretation, suggesting the need for reassessment of this process.

7.2 Associations between 4G and Full Fibre coverages

Over the past five years, 4G and Full Fibre coverage have increased across the UK. All nations maintained over 60% 4G availability throughout this period. Notably, Northern Ireland experienced a dramatic rise in Full Fibre coverage, starting below 30%, surpassing 4G in 2022, and reaching nearly 90% by 2023.

In 2023, larger cities had higher availability of both 4G and Full Fibre, while rural areas had weaker availability of both. This trend mirrored the previously explained 4G coverage patterns. England clearly followed this trend, with a pronounced rural-urban disparity in 4G and Full Fibre advancement. However, Northern Ireland was an exception, with high overall connectivity despite relatively low 4G coverage, thanks to significantly high Full Fibre availability. This outcome was influenced by the use of K-means clustering with centroids determined by percentile statistics. There is an opportunity to reconsider the clustering approach, as employing different centroid points might yield a different outcome for Northern Ireland.

England and Wales demonstrated progress in development, featuring a range of groups with high, medium, and low coverage in both 4G and Full Fibre. In contrast, Scotland had relatively low coverage. Focusing on improving connectivity in Scotland should be a key consideration for enhancing overall coverage in both 4G and Full Fibre.

8. Reflect

Data cleaning and investigation were conducted for TMA02, as detailed in the attached notebooks and Appendix 1. Previously, the Full Fibre data for the five-year period was prepared using MongoDB. At the stage of EMA, it was straightforward to import and analyse the data. Although there is a substantial amount of 4G data for each local authority every year, processing the data for analysis was manageable.

While 4G availability increased generally over the five-year period, some areas experienced fluctuations in availability percentages. Instead of merely taking the highest and lowest values to analyse increases and decreases, this time the recent year was compared with previous years to address how to improve the current situation.

Regarding the K-means technique, allowing K-means to automatically select and refine centroids did not provide sufficient clustering despite several trials. Therefore, centroids were manually decided based on statistics, which significantly aided in clustering into three groups.

As mentioned in the conclusion, K-means categorised Northern Ireland as having high availability of both 4G and Full Fibre. Despite the effectively well-located centroids, drawing conclusions about these areas was challenging.

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9. References

Beckett, M. (2024) ' What is full fibre broadband, and is it available to you?' USwitch [Online]. Available at https://www.uswitch.com/broadband/guides/full-fibre-broadband/ (Accessed 15 May 2022).

Clark, A. and Baker, C. (2024) *'Rural mobile coverage in the UK: Not-spots and partial not-spots',* UK Parliament, 1 March 2024 [Online]. Available https://commonslibrary.parliament.uk/research-briefings/sn07069/ (Accessed 21 May 2024).

Goswami, S. and Chakrabarti, A (2012) *'Quartile Clustering: A quartile based technique for Generating Meaningful Clusters'*, Cornell University, 19 Mar 2012 [Online]. Available https://arxiv.org/abs/1203.4157 (Accessed 21 May 2024).

O'Halloran, J. (2022) *'UK government needs to rapidly fulfil full-fibre ambitions',* ComputerWeekly.com, 13 Oct 2022 [Online]. Available https://www.computerweekly.com/news/252526041/UK-government-needs-to-rapidly-fulfil-full-fibre-ambitions (Accessed 21 May 2024).

Pannell, R. (2023) *'The Danger of Averages: Why They Can Mislead and Misrepresent'*, Leanscape, 8 September 2023 [Online]. Available https://leanscape.io/the-danger-of-averages-why-they-can-mislead-and-misrepresent/#:~:text=While%20averages%20can%20provide%20a,ineffective%20strategies%20and%20misguided%20expectations (Accessed 27 May 2024).

techUK (2023) *Ofcom Connected Nations 2023 outlines full-fibre take-up running at 28%,* 19 Dec 2023 [Online]. Available https://www.techuk.org/resource/ofcom-connected-nations-2023-report-outlines-full-fibre-take-up-running-at-28.html (Accessed 21 May 2024).

10. Appendix 1: Notebooks

Full details of the data processing and analysis are given in the following Notebooks.

Notebook	**Contents**
K7966111_EMA_Q1.ipynb	Investigation for Question 1
K7966111_EMA_Q2.ipynb	Investigation for Question 2
K7966111_project_diary.ipynb	Preparation for analysis guided the research
K7966111_TMA02.ipynb	Preparation for Full Fibre data with MongoDB from TMA02

11. Appendix 2: Data catalogue

All data used in this report is licensed under the Open Government Licence v3.0, linked at: https://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/

Full Fibre and 4G data used in this report came from 'Connected Nations and infrastructure reports', hosted on Ofcom https://www.ofcom.org.uk/research-and-data/multi-sector-research/infrastructure-research.

Geojson data used in this report came from ' Local Authority Districts (December 2022) Boundaries UK BUC' hosted on Office for National Statistics, linked at: https://geoportal.statistics.gov.uk/datasets/ons::local-authority-districts-december-2022-boundaries-uk-buc-2/explore?location=55.012777%2C-3.860421%2C5.91.