CS910: Coursework (1113858)
Broadband Availability and Speed vs. Population

Abstract—**This paper will analyse data relating to the availability and quality of internet connection technologies available throughout the United Kingdom, and contrast them with local population data. The paper will then attempt to identify trends connecting the two, endeavouring to identify a pattern between internet data and the users of the internet service.**

I. INTRODUCTION

In an world where having access to the internet is becoming more important, a growing number of people are getting connected. Internet was traditionally sent entirely over copper wires, but this kind of internet transmission is being phased out and replaced with a fibre alternative. Increasingly, people may also opt for mobile broadband, which is internet transmitted via mobile phone networks. BT Openreach has a majority on ownership of fibre networks in the UK, with Virgin Media also having a large network. Fixed-line services such as these tend to be for more intensive use, regularly offering unlimited data plans, with other forms of internet tending to be capped [1]. This paper will analyse the availability and speeds of different kinds of internet, and how this relates to the local population. Data analysis techniques will be used in order to detect trends, such as whether certain attributes of an areas population can affect the availability and quality of local internet. A secondary aim of the paper will be to analyse the relationship between internet suppliers and the population via social media.

II. BACKGROUND

Technology has moved swiftly since the introduction of the internet. Some different types of services are:

- Digital Subscriber Line - This provides internet access using a telephone network. The most common type of Digital Subscriber line is known as 'Asymmetric Digital Subscriber Line', where the download speed is higher than the upload speed. The biggest provider of Digital Subscriber Line in the United Kingdom is BT Openreach [2]. Speeds can reach up to 24Mbps, depending on the technology used.
- Fibre - Fibre broadband provides much faster internet services, partly through the conventional telephone system. The most common type offered is 'Fibre-To-The-Cabinet', where data travels through fibre cables from the Internet Service Provider to the exchange, and then the standard copper telephone lines from the exchange to the users home, with speeds reaching a maximum of 76Mbps [1]. The largest fibre broadband provider in the United Kingdom is BT Openreach [2]. An alternative way to send fibre broadband is over optical fibre or coaxial cables. Current significant providers of cable based internet are Virgin Media and Smallworld Cable, who offer speeds of up to 152Mbps [3].
- Mobile - For areas lacking fixed-line services, or for where fixed-line services may only provide slow speeds, another alternative is mobile broadband. Common providers are mobile networks EE and Three, however, mobile broadband is prone to data caps, and may therefore be unsuitable for heavy users [4]. EE have recently launched the worlds fastest mobile network in London, offering speeds of up to 150Mbps [5].

Some methods of internet delivery may be a users only option; For example, a user from a rural area may not have access to fibre internet, and may have to use slower Asymmetric Digital Subscriber Line or mobile broadband. This paper will analyse relevant data sets relating to internet availability, and see if there is a correlation between this and certain population attributes, such as the age or occupation of the local population, and the paper will then analyse the relationship between the internet suppliers and the population over social media.

III. LITERATURE REVIEW

A. Broadband deployment and the bandwagon effect in the UK

In this article, Deshpande (2013) describes the demand for the evolution from slower dial-up internet to high-speed broadband internet in the United Kingdom [6]. He argues that a combination of a desire for faster speeds and a fall in prices lead to the swift movement towards fibre broadband.

B. 3G Evolution: HSPA and LTE for Mobile Broadband

This book focuses on the development from 3G to 4G mobile technologies [7]. HSPA and HSPA+ are considered particularly well-performing 3G technologies, occasionally being referred to as '3.5G'. This book therefore has been useful in order to gain more of an insight in how mobile networks can deal with an increasing quantity of data.

IV. THE DATASETS

Data sets to be used for this investigation are listed below:

A. Ofcom UK Broadband Speed Data 2013

Ofcom is the United Kingdom's regulatory and competition authority for the communication industry. They offer a data set which breaks down internet statistics to a postcode level, with the data offered through data.gov.uk [8]. The same information is also offered at a local authority level. Example information held is the average speed and take-up. This data from October 2013 was the latest available.

B. BT Areas

Two data sets will be used when looking into deployment of BT Broadband: The first will reveal the availability of BT's Fibre-To-The-Cabinet service, whilst the second will look at their Asymmetric Digital Subscriber Line service. This data was obtained from SamKnows.com [9], a well-known website detailing internet availability.

C. Virgin Media Areas

Similarly to the above data on BT areas, data will also be obtained from SamKnows.com [9] detailing availability of internet services from Virgin Media [18].

D. Smallworld Cable Areas

Smallword Cable are a small company providing broadband, phone and television services to the north of England, as well as Scotland [11]. They have recently been bought by Virgin Media. Data on Smallworld Cable's footprint has been obtained from SamKnows.com [9].

E. Mobile Internet

Ofcom-provided data on the availability of 2G and 3G Mobile Phone signals has been obtained from data.gov.uk [12]. Interesting attributes in this data are how many operators cover a particular city, as well as the average amount of data used per premises each month.

F. Population Data

1) Age: Data obtained from the 2011 ONS census will be used in order to gather information on the distribution of different age ranges throughout the United Kingdom [13], to see if it can be related to internet availability.
2) Occupation: Further investigation will be done in order to see if the distribution of occupations in a particular geographical area would affect the availability and quality of internet provided. This information has been obtained from the ONS website from the 2011 census [14].

G. Social Media Data

Information will be obtained from internet suppliers Twitter and Facebook pages relating to the number of 'followers' and 'likes' that each supplier has gained [20, 21]. This will then be compared to their number of subscribers to investigate as to whether their number of followers and likes is proportional to their number of subscribers.

V. Hypothesis

It may be sensible to predict a strong correlation between the availability and quality of internet with the age of the population and professional occupations, as younger or working people may use the internet more frequently. It could therefore be predicted that a large city with a larger percentage of younger people, such as Birmingham, would have faster and more widely available internet than a smaller, less industrial area.

VI. Software & Techniques

The data obtained is a mixture of Microsoft Excel formatted files, as well as Comma Separated Value files. The following tools will be used to analyse the data:

A. Microsoft Excel

Microsoft Excel is a well-performing data analysis tool. Advantages of Microsoft Excel include its ease of use, and its large amount of documentation and support.

B. Command Line Tools

Command Line Tools are a simple method for analysing data. These tools will be used for performing basic data analysis.

C. Awk

Awk is another command line interface, providing another method for analysing data. It will be used in a similar way to other command line tools.

D. R

R is a more advanced data analysis tool when compared to the command line tools. Libraries such as 'rworldmap' will be used in order to increase functionality.

E. Weka

Weka provides a graphical user interface, as well as a command line interface, for data analysis. It's main use in the project will be for classification and clustering.

F. SQL

SQL is a language used to manipulate data stored in a database. It will be used as part of the Data Cleaning phase in order to select particular data records.

VII. Data Cleaning

A. Ofcom UK Broadband Speed Data 2013

The data is ready for analysis without cleaning.

B. BT Areas

Strangely, the data for BT's Fibre-To-The-Cabinet exchanges included latitude and longitude information for roughly half of the exchanges upon download; However, the remaining figures had to be calculated. This was done by firstly using standard SQL, as the use of 'NoSQL' or 'MapReduce' was deemed to not be necessary, due to the relatively small size of the data. The exchanges with the missing information were gathered using the following SQL command:

```
SELECT * FROM btfttc
WHERE Longitude IS NULL
```

From the result, the 'Exchange Name' attributes are converted to longitude and latitude information in order to be plotted using R.

C. Virgin Media Areas

The beginning of the data analysis phase will involve plotting a graph in R of all areas covered by the internet service providers. This will therefore involve converting the 'Exchange Name' attribute of the data into latitude and longitude information. The exchange names 'Arkwright', 'Goscote', 'Docklands Zone Two', 'Bloomsbury', 'Whitehall' and 'Waterhayes Farm' were not recognised as valid places, and therefore excluded. The tool used to convert exchange names into latitude and longitude information was provided by Doogal.co.uk's Batch Geocoding system [15].

D. Smallworld Cable Areas

Smallworld Cable are a very small company, having only seven exchanges; Hence, the data set provided concerning them is very small. Similarly to the other internet service providers, their exchange names have been converted to latitude and longitude information in order to be plotted on a map using R.

E. Mobile Internet

Similarly to the other mobile operators, this data has taken local authority names and converted them to latitude and longitude information in order to allow the data to be plotted on a graph using R. The remainder of the data looks ready to be used, otherwise.

F. Population Data

1) Age: Each of the area names was converted to Longitude and Latitude information, for use in plotting graphs in R. Furthermore, whilst the numbers of people aged 65 or over was provided by the data, this was converted to a percentage for each area in order to see which areas have a percentage of people aged 65 and over which is greater than the national average. The remainder of the data looks ready to be used, otherwise.

2) Occupation: Percentages of the population from a range of different occupation groups were calculated, and then compared to the overall average of the United Kingdom. This will allow the data to be plotted on a graph using R. The remainder of the data looks ready to be used, otherwise.

G. Social Media Data

The Social Media data will be a small analysis involving comparing the number of Twitter followers and Facebook likes that a particular internet supplier has, with their true number of customers. This will then be compared, to see if the number of Twitter followers and Facebook likes is proportional to the number of customers. As this data will be lifted directly from the internet supplies Twitter and Facebook pages, there will be no data cleaning carried out.
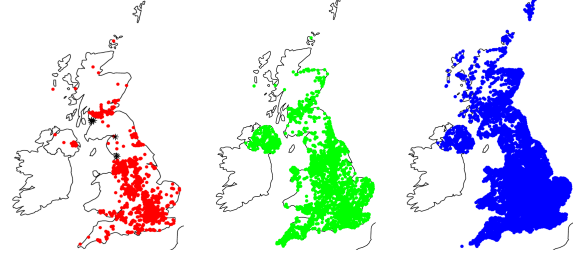

Fig. 1. Virgin Media (Left, Red), Smallworld Cable (Left, Black), BT's Fibre-To-The-Cabinet (Middle, Green) and BT's Asymmetric Digital Subscriber Line (Right, Blue).

VIII. DATA ANALYSIS

A. Fixed-Line Internet

By using Awk and command line tools, it was found that the average speed of fixed-line internet in the United Kingdom is 16.32Mb/s. This was found by analysis the Ofcom UK Broadband Speed Data from 2013. The next task was to produce a visual representation of areas in the United Kingdom with access to specific types of internet. Figure 1 represents all areas being served by internet, be it from Virgin Media, which is represented on the left by red circles, Smallworld Cable, which is represented on the left by black crosses, BT's Fibre-To-The-Cabinet services, which is represented in the middle in green, or BT's Asymmetric Digital Subscriber Line which is represented to the right in blue. The map was created using the 'rworldmap' library for R. As can be seen, Virgin Media tends to focus more on the three largest cities in England, those being London, Birmingham and Manchester. Another point of interest that can be raised from this visualisation is the lack of much overlap between Virgin Media and Smallworld Cable. This may have been attractive for Virgin Media as they were buying Smallworld Cable, as they would be expanding their network into new areas.

In comparison with Virgin Media and Smallworld Cable, BT's footprint is on a much large scale. This could be attributed to BT being the only company that is provided with public money in order to improve superfast broadband rollout in the United Kingdom [16]. It could also be attributed to the OpenReach network, which is the network the BT use, not only being used by BT but also by a multitude of different other operators. A particular difference is noticed in the south-east of England, as well as in Northern Ireland, where BT's footprint is much larger than that of Virgin Media's. When plotting this graph, unfortunately, 'Baillies Mills', 'Ramsey Hunts', and 'Sealand Rcc' were not found, and were hence removed from the data.

In comparison, BT's Asymmetric Digital Subscriber Line footprint is even bigger. Having been around much longer than Fibre-to-the-Cabinet technology, and also with this technology being transmitted via traditional telephone lines, Asymmetric Digital Subscriber Line appears to have had a more advanced rollout. However, 'Baillies Mills', 'Bloomsbury Aka Howland St', 'Cleish Hills', 'Dutton Diffeth', 'Kilkenzie', 'Ramsey Hunts', 'Sealand Rcc',
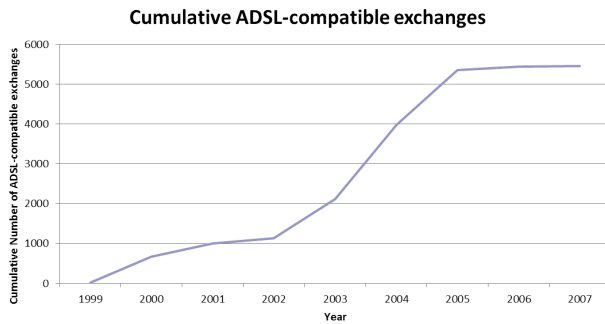
Fig. 2. Demonstrating the cumulative rollout of BT's Asymmetric Digital Suscriber Line system.

Fig. 3. The coverage of mobile internet.

Fig. 4. Areas with at least 75% coverage by all 3G networks.

'Waterhayes Farm' and 'Whitehall' were not recognised and hence removed. When BT's Fibre-to-the-Cabinet map is compared to their Asymmetric Digital Subscriber map, it can be seen that BT's Fibre-to-the-Cabinet service still lags behind Asymmetric Digital Subscriber Line, particularly in the north of Scotland and in central Wales.

Unfortunately, upgrade dates for BT's Fibre-to-the-Cabinet exchanges are not provided, however, upgrade dates for when Asymetric Digital Subscriber Line exchanges went live are available. Figure 2 presents a cumulative graph of the years in which these exchanges went live, which was produced using Microsoft Excel. From this, it can be seen that the service was fully implemented in a period of eight years. Given that BT's Fibre-to-the-Cabinet service was launched in January 2010 [17], it could be estimated that a full rollout of these faster speeds will be completed in 2018. However, BT seem to be ahead of scheduling, having switched over half of the exchanges to Fibre-to-the-Cabinet as of 2014.

B. Mobile Internet

Figure 3, which was generated in Microsoft Excel, shows both 2G and 3G coverage of premises, and by how many operators cover those premises. 2G can be defined as the second generation of mobile signals, capable of calls, texts and slow internet access, whilst 3G is capable of calls, texts and faster internet access. Data on the fourth generation of mobile internet, 4G, was unavailable, however, 4G may be seen as a bad current alternative to fixed-line broadband, due to data caps and low coverage. The only mobile network operator with an unlimited tariff on 4G internet is Three; However, this is unlimited only in terms of phone data, and they then provide a 4GB tethering limit on phone plans [18], and according to a recent Ofcom report, Three has the lowest coverage out of all of the operators [19].

Due to the slow speed of 2G, it is not considered a viable method of browsing the internet. Therefore, for the purpose of generating a map, 2G will be excluded. Figure 4 represents a map of all areas of the United Kingdom with a 3G mobile coverage of at least 75 % by all operators. As can be seen from this map, reliable, high-quality 3G coverage is generally limited to big cities, being only available in large quantities in London, Birmingham, Manchester, Liverpool, Newcastle,
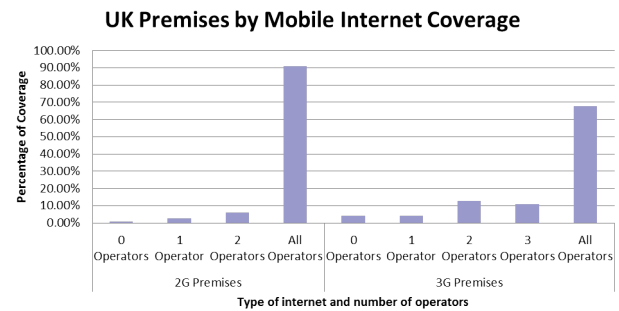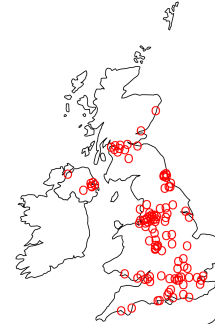
Cardiff, Glasgow and Belfast. Speed may also hinder performance of a mobile internet connection. The aforementioned Ofcom study found an average of the following download speeds when using mobile internet connections [19]:

- EE: 6.8Mb/s
- O2: 5.6Mb/s
- Vodafone: 6.7Mb/s
- Three: 5.2Mb/s

Figure 5 presents a cluster graph, as generated in Weka, clustered based on longitude and latitude information, which matches the geography of the United Kingdom. Four clusters were chosen in order to match the number of countries of the United Kingdom, and to try and form one cluster per country. What can be seen instead from the cluster graph is that better mobile coverage seems to be skewed much more towards England, with three of the four clusters being mainly in England. A fourth cluster is in Northern Ireland, but that could be seen more as due to the fact Northern Ireland is geographically separate from Great Britain.

Figure 6 compares the coverage of each mobile operator with its average speed, by using a graph created using R. There is a slight negative correlation, but nothing too steep. This was probably due to Three's disappointing result, as EE holds a 98% coverage and the highest average speed at 6.8Mb/s. Overall, using mobile internet as a replacement for fixed-line internet would not be recommended.

C. Population Data

1) Age: This section will analyse the age distribution across the United Kingdom, and more specifically, which areas
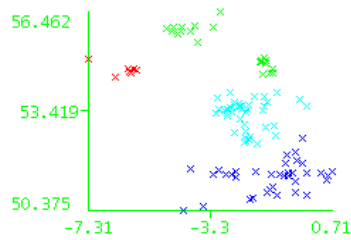
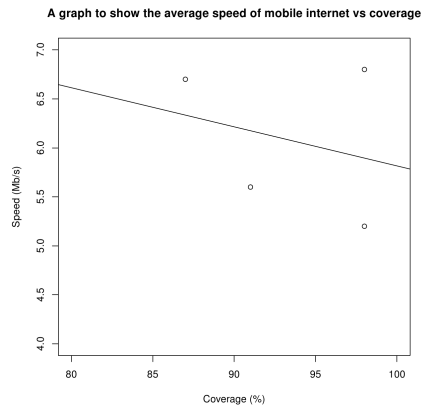Fig. 5. A cluster graph showing 3G coverage of the mobile networks.

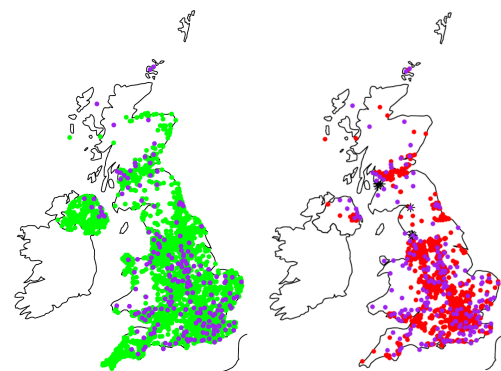Fig. 6. Coverage vs Speed of the main mobile networks.

Fig. 7. Left: BT's Fibre-to-the-Cabinet availability (Green) in areas with an above average percentage of those of retirement age (Purple). Right: A similar plot, but with Virgin Media (Red) and SmallWorld Media (Black) in areas with an above average percentage of retirement age (Purple).
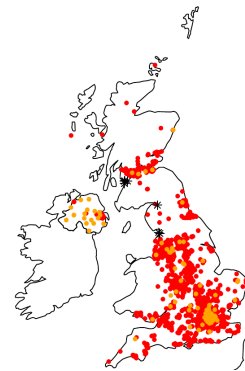

Fig. 8. Showing Virgin Fibre-to-the-Cabinet availability (Red Circles) and Smallworld Cable availability (Black Crosses) in areas with a below average percentage of those of retirement age (Orange Circles).

have the largest percentage of people at retirement age, which currently sits at an age of 65 or greater. Microsoft Excel was used to analyse the 2011 Census data regarding population. From this, a percentage of citizens over the age of 65 was calculated for each local authority, as well for the United Kingdom as a whole, which currently sits at 16%. The highest percentage was found in the southern town of Christchurch, which sat at 30%, whereas the lowest percentage was a mere 6% in Tower Hamlets. In order to gain these percentages, further calculation had to be carried out on the initial data. The data provided numerical counts for all people of certain ages for each local authority, as well as counts of people in five year age intervals per local authority. Furthermore, this data was provided on an overall United Kingdom level. This data could therefore be used to calculate the national average percentage of those of retirement age, as well as the average for each local authority.

Given the national average of 16%, a map was plotted showing all local authorities in the United Kingdom where the percentage of people at retirement age was higher than the national average. The results of this were placed over the previous map showing the locations of BT's Fibre-to-the-Cabinet service, and this is shown in the left map of Figure 7. As can be seen from Figure 7, BT's wide availability of their Fibre-to-the-Cabinet service has enabled them to be present in virtually all areas with an above average percentage of people of retirement age. Figure 7 also compares Virgin Media and Smallworld Cable's footprint with areas with an above average percentage of people of retirement age. This shows a different result when compared to BT's footprint. Whilst one of either Virgin Media or Smallworld

Cable's services tend to be available in areas with an above average percentage of retirement age, there is a set of areas in the north of Scotland, north of England, north of Northern Ireland, north of Wales, and south-west of England where neither services are available.

Figure 7 itself is little persuasion to come to a conclusion that internet rollout may be swayed by the age of an areas citizens. Figure 8 however shows the reverse of Virgin Media's map from Figure 7, that being the availability of Virgin Media combined with Smallworld Cable in areas with a below average percentage of those of retirement age, and hence an above average percentage of those of working age or school age. In this map, we can see that, taking Great Britain only into account due to Virgin Media's very minor presence in Northern Ireland, either Virgin Media or Smallworld Cable is available in every area with a below average percentage of those of retirement age.

Figure 9 represents cluster maps based on longitude and latitude information, comparing BT with a the combination of Virgin Media and Smallworld Cable. What is interesting is that the two maps have very similar clustering, for example, with two clusters in the south east of England, one in Scotland and three in the north of England. From this, we can form a conclusion that the rollout of superfast broadband ac-
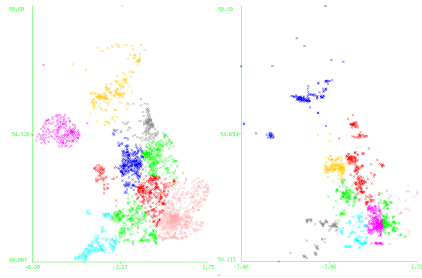
Fig. 9. Showing BT's cluster map (Left) vs Virgin Media and Smallworld Cable's cluster map (Right).

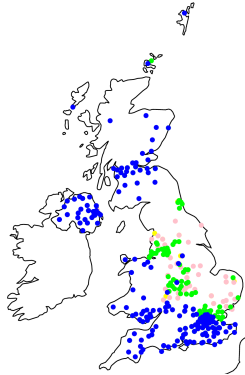Fig. 11. Figure 14 placed on top of Virgin Media and Smallworld Cable's footprint.

Fig. 10. A graph showing above United Kingdom averages for those in a Professional Occupation (Yellow), Managers, Directors or Senior Officials (Pink), Administrative and Secretarial Roles (Green), and Associate Professional and Technical Occupations (Blue).

cross the United Kingdom, even between different companies, may follow a similar pattern of rollout and availability. From all of this information combined, we can form a conclusion that there is a slight correlation between the age distribution of an area, and its access to superfast broadband. However, due to the wide availability of BT, combined with Virgin Media and Smallworld Cable's growing influence across the United Kingdom, the correlation is only slight.

2) Occupation: It is acceptable to believe that some occupations rely more on internet access than others - an office block of hundreds of staff would require a faster internet connection than a small pet shop, which may not even require an internet connection at all. For this section, information obtained from the 2011 census from the ONS will be used to see how areas with higher than average percentages of certain occupations relate to the rollout of superfast broadband. Firstly, an average of the entire United Kingdom was calculated for the occupation groups within the data. For the purpose of this experimentation, the following four occupation groups have been chosen:

- Managers, Directors and Senior Officials,
- Professional occupations,
- Associate professional and technical occupations,
- Administrative and secretarial occupations,

Figure 10 shows these four occupation groups plotted onto a graph. Surprisingly, what can be seen is that outside of London, there is little overlap between those in an 'Associate Professional and Technical Occupation' role with the other three roles. Figure 11 plots this data on top of Virgin Media
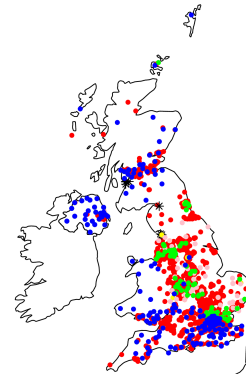
and Smallworld Cable's footprint.

From this, we can see that there is a strong correlation between areas covered by Virgin Media and area which have a higher than average number of Administrative and Secretarial roles. These tend to be spread over England, and are all covered by Virgin Media's services. Director's and Senior Officials, as well as Professional Occupations, are similar in that they also tend to be popular in areas which Virgin Media or Smallworld Cable have covered.

However, areas which have a large number of Associate Professional or Technical Operations tend to be spread more across different geographical areas, particularly in southern England. Here, coverage of Virgin Media's services is much more sparse. Again, Northern Ireland has been excluded due to Virgin Media's poor footprint there.

IX. CLASSIFICATION AND FORMING A MODEL

To further investigate if there is a relationship between occupation data and broadband availability and speed, a model was formed. Firstly, the data had to be processed in order to produce categoric attributes, necessary for classification to be carried out. 'Above' and 'Below' categories were created based on all of the nine occupational groups from the data, with 'Above' meaning that there was an above average percent of people in that area being in that occupational group, and 'Below' meaning the reverse.

The class attribute chosen is an attribute which is either 1 or 0, with a 1 representing the availability of Virgin Media in an area, with a 0 representing no availability of Virgin Media in an area. Therefore, the aim of the model was to predict the availability of Virgin Media's services based on the distribution of occupation groups in a particular area. Given the previous results of this projects analysis, it is expected that a fair amount of correctly classified instances can be achieved by analysing the occupation groups.

The first was a Naive Bayes classification. Using it's default parameters, this held a 73.1% Correctly Classified Instances rate. Precision for a value of 0 was 0.783, and for a value of 1 was 0.308. Changing the parameters did not affect results. The second was an SVM classification. Using it's default parameters, this held a 77.3% Correctly Classified Instances
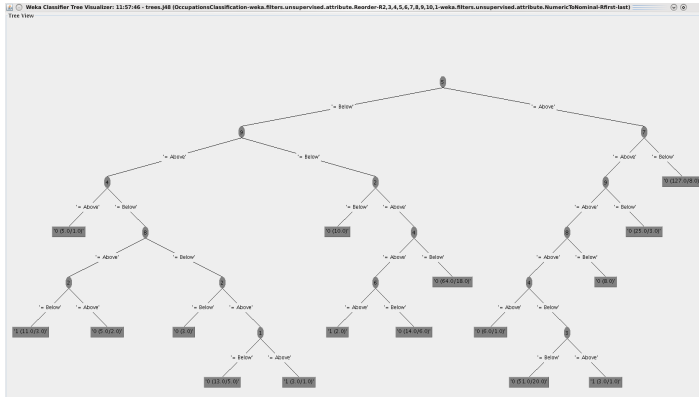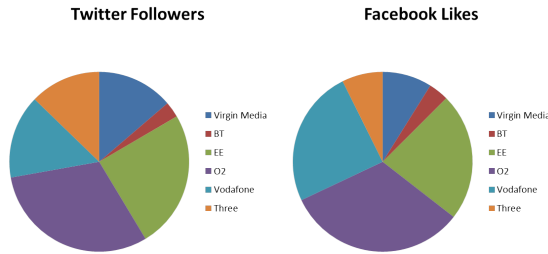
Fig. 12. The J48 decision tree.

Fig. 13. Twitter Followers vs Facebook Likes for internet suppliers.

rate. Precision for a value of 0 was 0.773, and for a value of 1 was 0. Changing the parameters did not affect the result. The third was a J48 decision tree classification. This also achieved a 77.3% Correctly Classified Instance rate, and also achieved a 0.788 precision value for 0, and a 0.5 precision value for 1. The consistency of accuracy of roughly 75% on each classification emphasises the relation between Virgin Media internet availability and occupation groups, but shows that there is not a strong correlation between the two.

X. SOCIAL MEDIA ANALYSIS

As of writing, here are each suppliers number of Twitter 'followers' followed by Facebook 'likes' [20] [21]:

- Virgin Media: 114000, 299500.
- Smallworld Cable: Have been replaced with Virgin Media's pages due to the merger of the two companies.
- BT: 23700, 121869.
- EE: 206000, 774789.
- O2: 256000, 1094138.
- Vodafone: 125000, 830246.
- Three: 106000, 247825.

What can be seen is that the Facebook 'likes' of a internet supplier is always greater than their number of Twitter 'followers'. Figure 13 shows the proportion of social media followers that each supplier possesses. Surprisingly, information pulled from Statista [22] shows that EE has a smaller percentage of Twitter 'followers' and Facebook 'likes' than its number of subscriptions would suggest, as EE has a huge 33% United Kingdom market share. Figure 14 demonstrates the percentage of social media 'followers' and 'likes', vs.
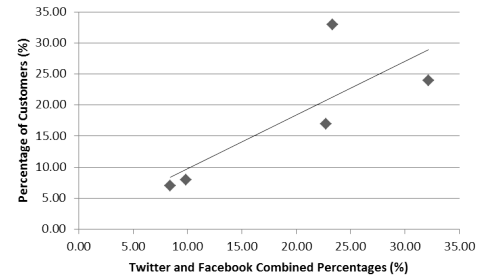

Fig. 14. A graph showing social media likes and follows vs market share.

numbers of subscribers for the major UK mobile networks. However, some of these companies, mainly Virgin Media, Smallworld Cable, BT UK and EE, provide services other than internet, such as television or fixed-line telephone, and therefore some of these social media followers and likes may have been gained from that area of the business.

From Figure 14, we can see that the relationship between a internet suppliers combined number of Twitter 'followers' and Facebook 'likes' is linearly correlated to their number of customers [22]. The is only a single exception to this rule, that being the UK's largest mobile network, EE. The reason for their comparatively smaller number of social media likes and follows may be due to how EE is a newer brand when compared to the rest of the companies, having merged from popular brands Orange and T-Mobile back in 2012. Many of the other companies social media 'likes' and 'follows' may therefore be from dormant accounts from pre-2012.

But how does this relate directly to the study presented in this paper? This paper has shown that the footprint of Virgin Media is smaller than that of the rest of the internet suppliers; However, their total number of social media followers is not far smaller than the other suppliers. This could demonstrate that Virgin Media's customer-base are far more technology-oriented and whom interact more with their internet service provider more. Virgin Media may therefore take the location of collections of their more vocal potential customer base when considering expanding their network. However, further study would be needed to conclude this.

XI. CONCLUSION

The aim of this paper has been to compare the quality and availability of fixed-line and mobile internet in the United Kingdom, and compare it to population data, specifically data which relates to age, occupation, and use of social networks. Whilst a correlation was found, it is not as strong as initially expected. It appears that if internet suppliers do take into account the age and occupation of their customers, then they also take into account a variety of other factors when planning their rollout.

What the paper has found, however, is that whilst outside of London and central England, Virgin Media's Fibre-To-The-Cabinet service has sparse availability, many professional jobs such as 'Associate Professional and Technical Operations'

are generally outside of London and Central England. This also applies to areas with at least 75% coverage by all 3G networks. This demonstrates expansion opportunities for both Virgin Media and the mobile networks.

XII. EXTENSIONS

Possible extensions to this research are as follows:

1) 4G mobile internet has allowed for more demanding tasks to be carried out over the faster mobile internet speeds. Mobile networks are rolling out 4G signals, generally starting in large cities and moving their way outwards. It would be interesting to investigate as to what criteria are used to choose which areas to upgrade to 4G technologies first.

2) The rollout of fibre broadband requires a lot of time, effort and money laying physical cables to many homes. Should BT or any other fixed-line internet service provider acquire an amount of 4G mobile spectrum, would this be a viable temporary alternative to fixed-line services for high speed internet access for those in rural areas?

3) Despite having only 7% of the mobile market share in the United Kingdom, mobile network 'Three' carries over 45% of the United Kingdom's mobile data [23]. Why is this the case, and is there any particular characteristic that Three's customers have in common? Could this be used by other internet suppliers to detect how much data a potential customer may use?

XIII. BIBLIOGRAPHY

[1] Increase Broadband Speed. (2013). What is Fibre Broadband? Available: www.increasebroadbandspeed.co.uk/what-is-fibre-broadband. Last accessed 26th Nov 2014.

[2] Openreach. (2005). Openreach. Available: http://www.openreach.co.uk/orpg/home/home.do. Last accessed 26th Nov 2014.

[3] Virgin Media. (2012). Compare Broadband. Available: store.virginmedia.com/broadband/compare-broadband/index.html. Last accessed 26th Nov 2014.

[4] MoneySuperMarket. (2010). Compare Mobile Broadband Deals - MoneySuperMarket. Available: moneysupermarket.com/broadband/mobile-broadband/. Last accessed 26th Nov 2014.

[5] Ofcom. (2014). Measuring mobile broadband performance in the UK. Available: stakeholders.ofcom.org.uk/binaries/research/broadband-research/mbb-nov14.pdf. Last accessed 26th Nov 2014.

[6] Advait Deshpande. (2013). Broadband deployment and the bandwagon effect in the UK. 15 (1), 34-47.

[7] Erik Dahlman, Stefan Parkvall, Johan Skold, Per Beming (2007). 3G Evolution: HSPA and LTE for Mobile Broadband. Oxford: Academic Press.

[8] Data.gov.uk. (2014). Broadband coverage. Available: http://data.gov.uk/dataset/broadband-coverage. Last accessed 26th Nov 2014.

[9] SamKnows. (2014). Various Internet Supplier Data. Available: https://www.samknows.com/. Last accessed 26th Nov 2014.

[10] Virgin Media. (2012). Superfast Broadband, TV Phone packages from Virgin Media. Available: http://store.virginmedia.com/index.html. Last accessed 26th Nov 2014.

[11] Smallworld Cable. (2001). Available: http://www.smallworldcable.com/Home. Last accessed 26th Nov 2014.

[12] Data.gov.uk. (2014). Mobile Phone Coverage. Available: http://data.gov.uk/dataset/mobile-phone-coverage. Last accessed 26th Nov 2014.

[13] Office for National Statistics. (2011). 2011 Census, Population Estimates by single year of age and sex for Local Authorities in the United Kingdom. Available: http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-294277.. Last accessed 26th Nov 2014.

[14] Office for National Statistics. (2011). Key Statistics and quick statistics for local authorities in the United Kingdom. Available: http://www.ons.gov.uk/ons/rel/census/2011-census/key-statistics-and-quick-statistics-for-local-authorities-in-the-united-kingdom—part-2/rft-ks608uk.xls. Last accessed 26th Nov 2014.

[15] Chris Bell. (2009). Batch geocoding. Available: http://www.doogal.co.uk/BatchGeocoding.php. Last accessed 26th Nov 2014.

[16]Nicole Kobie. (2013). Government leaves BT with monopoly on public broadband funds. Available: http://www.pcpro.co.uk/news/broadband/380659/government-leaves-bt-with-monopoly-on-public-broadband-funds. Last accessed 26th Nov 2014.

[17] Richard Wray. (2010). BT launches super-fast broadband. Available: theguardian.com/business/2010/jan/21/bt-launches-super-fast-broadband. Last accessed 26th Nov 2014.

[18] Three UK. (2011). Personal Hotspot on your phone. Available: http://support.three.co.uk. Last accessed 26th Nov 2014.

[19] Ofcom. (2014). 4G and 3G mobile broadband speeds research. Available: http://consumers.ofcom.org.uk/news/4G-3G-mobile-broadband-speeds-research/. Last accessed 26th Nov 2014.

[20] Twitter. (2008-2012). Various Internet Suppliers. Available: https://twitter.com. Last accessed 26th Nov 2014.

[21] Facebook (2008-2012). Various Internet Suppliers. Available: https://www.facebook.com. Last accessed 26th Nov 2014.

[22] Statista. (2013). Market share held by mobile phone operators in the United Kingdom (UK) as of February 2013. Available: http://www.statista.com/statistics/279993/market-share-of-mobile-phone-operators-in-the-united-kingdom-uk/. Last accessed 26th Nov 2014.

[23] Three UK. (2014). Three reports continued growth in profit and innovation. Available: http://www.threemediacentre.co.uk/Press-Releases/Three-reports-continued-growth-in-profit-and-innovation-370.aspx. Last accessed 26th Nov 2014.