Mobile signal strength measurement data from Network Rail's engineering trains

Information about the data files

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1. Overview

Since October 2017 Ofcom has been collecting data related to mobile signal strengths along the rail network in England, Scotland and Wales, using antennas mounted on the top of four of Network Rail's yellow engineering trains ("the yellow trains"). We are releasing the data collected between June 2018 and June 2019 under our open data policy, so that industry and policymakers can make full use of the information we have collected. This document outlines how we collected this data and provides guidance on what the data represents.

The data collected – in brief

We have collected mobile signal strength data along the rail network in Great Britain (i.e. England, Scotland and Wales) using antennas mounted on the top of four of Network Rail's yellow engineering trains, which are specialised trains used for monitoring and maintaining the track.

The data represents the strongest mobile signal (per mobile operator) received at the antenna on the roof of the train; it is therefore not representative of the mobile signal a passenger would expect to receive inside a train travelling on the same route, or an engineer would expect to receive working at track level. The data is neither representative of the quality of service a mobile phone would receive even if it was placed on the roof of the train, as we have not measured aspects such as capacity or handover, nor of the quality of on-board Wi-Fi passengers could expect to receive if this was provided, even though this often uses mobile signal as backhaul.

The data we have published shows the routes travelled by the yellow trains during the measurement period of June 2018-June 2019, therefore there may be some parts of the GB rail network which are not included in the dataset. Tunnels, in which the measurement equipment may not have been able to register any information, may also appear as gaps in the data.

The data includes measurements for 2G, 3G and 4G mobile signal. Measuring 5G mobile signal was outside the scope of this project, as operators had not yet started to deploy 5G at the time we began these measurements.

2. Methodology

2.1 This section outlines the methodology by which we have collected the measurements data, the equipment we have used and how we process the data once it is collected.

The measurement equipment

2.2 For each of the four engineering trains, we have used a custom measurement system rack-mounted inside the train carriage, connected to a radio frequency (RF) measurement antennas externally mounted to the top of the train at a height of approximately 3.8m above ground level; these antennas also receives GPS positioning signals. The measurement system comprises: a TSMW Frequency Scanner (the main measurement unit); a Windows mini PC that runs the data acquisition software and other automation scripts; hard drives for data storage and backup; and a 4G dongle for connectivity to the PC, and for monitoring the system and uploading data files back to Ofcom servers.

Automation

2.3 All the processes which run the system, from when the train is powered up to when it comes to a stop after its scheduled journey, are automated. This includes loading up the measurement software with the desired settings, frequent system stability checks, data collection, and export and upload of the data. Multiple scripts and configuration files are pre-installed in order to achieve this.

Remote monitoring

2.4 For any issues spotted or any configuration changes and checks etc, the system mounted on the train can be accessed remotely. The system is pinged continuously to check the status of the trains, and the data files received are monitored automatically for invalid measurements at a later stage.

Data collection

2.5 Raw measurement data are collected continuously when the trains are running and once the system has booted up. Every 20 minutes a subset of the measurements is exported to an ascii file, compressed and uploaded to an Ofcom server. These files report only the selected parameters and only the data from the best serving cells per MNO at any given measurement point. The entire measurement dataset, including data from all detectable cells, is recorded and held locally on the system, however this will only be retrieved at the end of the project (scheduled for March 2020) or if the system is returned for repair.

Post processing and calibration

2.6 Once the measurement data have been collected, the files are processed to prepare them for quality checks and further analysis. At this point, calibration offsets are incorporated to give the signal levels received at the antenna, rather than the uncalibrated figure measured by the system. We recommend the use of the calibrated values, which are included in the dataset in the columns marked by the prefix "cal_". The calibration offsets include the measurement system's gain and loss values for external antennas, cable losses etc.

Quality checks and automated monitoring

2.7 Measurement files are uploaded to an Ofcom server every 20 minutes. Once a day, an automated process runs checks on the past 24 hours' worth of data that filters out either invalid measurements or files. Any discrepancies in the measured data are flagged up through a variety of checks. For example:

- if the number of measurements is significantly different for any operator;
- if the location of the train is unknown; or
- if the measured signal levels are beyond a predefined threshold.

2.8 A measurement dashboard allows monitoring of any abnormalities and trends.

2.9 Finally, the data is also peer-reviewed manually to check for any inconsistencies

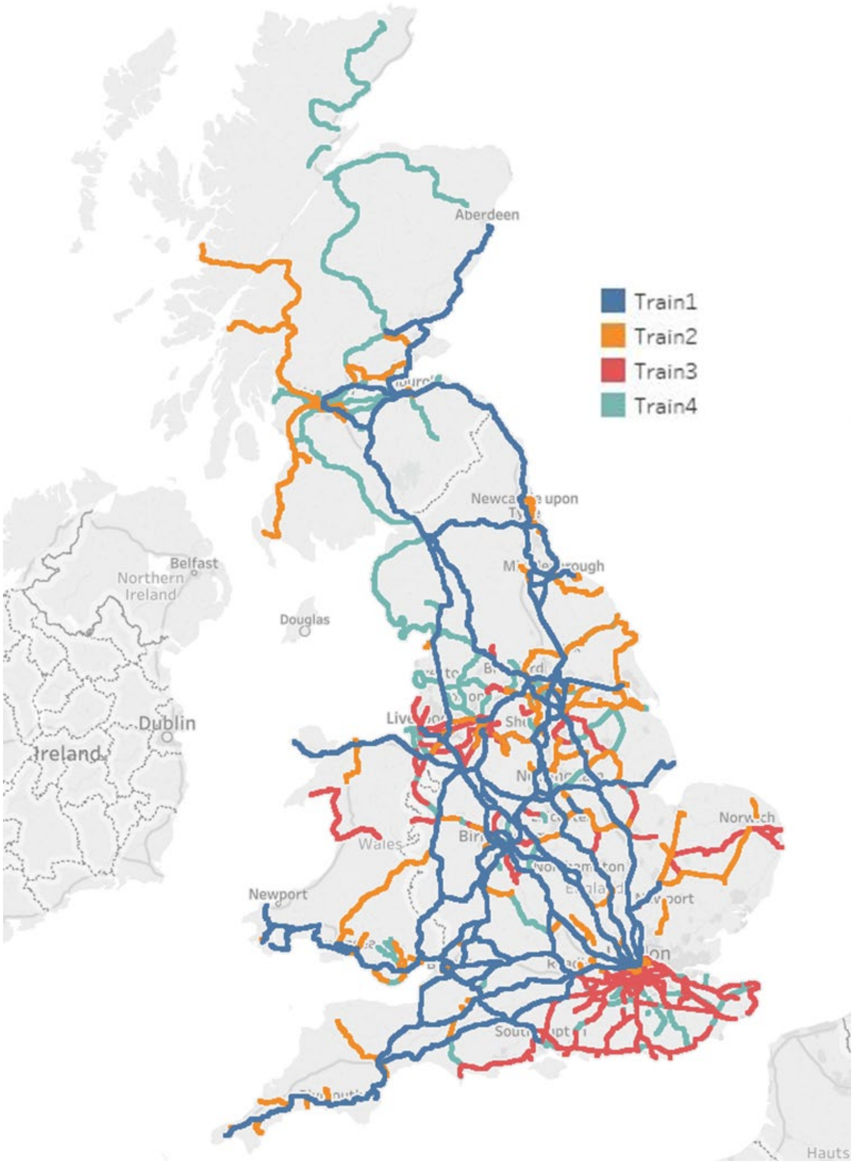
3. Locations and parameters reported

Routes covered

3.1 The map below indicates the routes travelled by the yellow trains during the measurement period of June 2018 to June 2019.[1] Please note that the routes taken by the trains are determined by Network Rail engineering need, not by Ofcom, and therefore while the data represents much of the GB rail network, this is made up of a patchwork of different journeys, where some routes will have been taken multiple times while some locations may only have been visited once.

[1] This map shows coverage reported by the trains. Therefore, while there are visible gaps on some routes, this does not mean that the yellow trains did not travel through these areas.

Figure 1: Map showing routes travelled by yellow engineering trains, June 2018 to June 2019



Parameters reported

3.2 The measurement data is provided in .csv files, with separate files for each mobile technology; i.e. one for LTE/4G, one for UMTS/3G and one for GSM/2G.

3.3 Each row represents one individual measurement point. The data points are not averaged or grouped in any way.

3.4 Table 1 below explains each of the column headings in the files.

Table 1: Measurement file header description

Field	Description	Example
Location and time parameters		
Latitude	Latitude reported by GPS in decimal degrees	53.98886
Longitude	Longitude reported by GPS in decimal degrees	-1.13712
Eastings	Converted from reported Latitude and Longitude values using OSGB36/EPSG 27700 standard	456675
Northings	Converted from reported Latitude and Longitude values using OSGB36/EPSG 27700 standard	455102
Speed	Speed of train, measured in km/h	78
datetime	Date and time of the measurement	24/06/2019 19:54:00
train	Which of the four yellow trains the measurement originated from	Train 1
Operator, band and cell information		
MNC	Mobile Network Code	10
Operator (LTE only)		EE
EARFCN (LTE only)	E-UTRA Absolute Radio Frequency Channel Number	1667
UARFCN (UMTS only)	UTRA Absolute Radio Frequency Channel Number	10588
Channel (UMTS only)	Centre frequency of the channel, along with a classification generated by the measurement system	ACD#6 (2117.6 MHz)
BCCH (GSM only)	Broadcast Control Channel	107
dlfreq	Download frequency, in MHz	956
SC (UMTS only)	Scrambling Code	335
CI	Cell ID	17513
PCI (LTE only)	Physical Cell Identifier	438
phylayercellid (LTE only)	Specific transmitter/sector id within a cell site	0
Received signal power levels and quality for each technology (LTE, UMTS, GSM)		
Ptotal	Total received power, measured in dBm	-62.16
RSRP (LTE only)	Reference Signal Received Power, measured in dBm	-84.99

Field	Description	Example
RSRQ (LTE only)	Reference Signal Received Quality, measured in dB	-11.99
SINR (LTE only)	Signal-to-Interference-plus-Noise Ratio, measured in dB	6.15
RSCP (UMTS only)	Received Signal Code Power, measured in dBm	-74.3
Ec/Io (UMTS only)	Ratio of energy per chip to interference level, measured in dB	-8.6
PSCH (GSM only)	Primary Synchronisation Channel power, measured in dBm	-62.56
C_I (GSM only)	Carrier to interference ratio, measured in dB	18.94
cal_Ptotal	Total power after considering the calibration offsets, measured in dBm	-56.84
cal_RSRP (LTE only)	Reference Signal Received Power after considering the calibration offsets, measured in dBm	-79.38
cal_RSCP (UMTS only)	Reference Signal Code Power after considering the calibration offsets, measured in dBm	-68.61
cal_psch (GSM only)	Primary Synchronisation Channel power after considering the calibration offsets, measured in dBm	-57.24

3.5 The entire measurement dataset, including data from all detectable cells (as opposed to just those with the strongest signal), is recorded and stored on hard drives on the trains. However, we are unable to retrieve this data without physical access to the trains and we have no plans to do so before the scheduled end of the project, currently expected to be March 2020.

4. Disclaimer

4.1 This data is a representation of the information and signal levels received using these specific systems with an antenna on the rooftop of the train. In addition to measurement uncertainties, there are several factors which could make these measurements non-representative for any other systems. For instance, the received signal on a handset at a different height to the train antenna or inside a train carriage may be quite different.

4.2 As such, this data should be seen as being indicative only; it is not suitable for use in safety critical operations.