3G Coverage Obligation Verification Model – MATLAB Source Code

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Contents

Section 1

Introduction

1.1 The 2100 MHz Third Generation Mobile Wireless Telegraphy Act licences include an obligation to provide, by 30 June 2013, an electronic communications network:

- that is capable of providing mobile telecommunications services to an area within which at least 90% of the population of the UK lives; and
- with a 90% probability that users in outdoor locations within that area can receive the service with a sustained downlink speed of not less than 768 kbps in a lightly loaded cell.

1.2 Ofcom published a statement on 9 May 2012 outlining the methodology for verifying compliance with this obligation (the 3G Coverage Obligation Verification Methodology)[1].

1.3 Compliance will be verified using a technical model that has been developed using the MATLAB numerical computing language. The version of MATLAB we used was the latest available to us (2013a with Parallel Tool Box). We do not warrant that the source code will work with any other version.

1.4 Ofcom has not published UK digital terrain, clutter or the population datasets as these are subject to data licences. The formats of these parameters are explained in this document. Users will have to define all necessary input data in order to successfully run the simulation model.

1.5 This document explains the source code files and input data that comprise the technical model used to generate the results for the 3G coverage obligation verification assessment:

- Section 2 describes the input parameters required by the model.
- Section 3 provides an overview of the simulation code.
- Section 4 outlines the individual files required by the technical model.

[1] 3G Coverage Obligation Verification Methodology
http://stakeholders.ofcom.org.uk/binaries/consultations/2100-MHz-Third-Generation-Mobile/annexes/methodology.pdf

Section 2

Input parameters

This section explains the required input parameters.

2.1 To assess mobile network coverage, the assessment tool uses UK terrain height data, UK population data, UK clutter data and mobile operator base station as input parameters.

2.2 In the 3G coverage obligation verification;

- a set of terrain height variables, dtm, have been created by Ofcom using Ordnance Survey "Land-form Panorama'' 50 meter resolution data,
- a set of population point variables, PC, have been created by Ofcom using the Census 2001 and Geopoint Plus R52 datasets, giving population data to a postcode unit level,
- the clutter associated with each population point is taken from the 50 meter resolution clutter dataset produced by Infoterra.

2.3 Due to data licence restrictions, Ofcom is not able to provide these variables. Users will have to create appropriate dtm and PC variables to assess network coverage.

Terrain Data

2.4 The terrain height of each base station location is extracted from a digital terrain map during the processing of base station data. The four closest values to the base station location are interpolated using bi-linear interpolation as described in ITU-R Recommendation P1144[2] to obtain the required terrain height.

2.5 For each National Grid Reference (NGR) square that contains base station information a MATLAB structure array variable dtm is required.

2.6 The dtm variable should contain data related to the associated NGR square and a buffer zone of 50 kilometres, this area is illustrated in Figure 2.2 of the 'Clarification for 3G Coverage Obligation Verification Data' document[3].

2.7 The dtm structure array has fields; sq, xmin, ymin, xmax and ymax which have single values and h which is a matrix of data. A description of dtm variable for 50 metre resolution data terrain height data is shown in Table 2.1.

2.8 Each dtm variable should be saved with the filename format 'xx.mat' where xx is the NGR square.

[2] ITU-R Recommendation P.1144, Guide to the application of the propagation methods of Radiocommunication Study Group 3, http://www.itu.int/dms_pubrec/itu-r/rec/p/R-REC-P.1144-6-201202-I!!PDF-E.pdf

[3] Clarification for 3G Coverage Obligation Verification Data, 7 June 2013. http://stakeholders.ofcom.org.uk/binaries/consultations/2100-MHz-Third-Generation-Mobile/annexes/3GCOV_clarification_approved.pdf

2.9 The location of the dtm variables should be defined within the simulation script 'Master_script.m' as TerrainFilePath, as described in section 3.2.

Table 2.1 Specification of dtm variable with 50m data resolution

Field	Format	Description	Data Unit
dtm.h	4000 x 4000 double	Terrain height above sea level	m
dtm.sq	string	NGR square	
dtm.xmin	1 x 1 double	Northing of first column of dtm.h to 1 metre resolution	m
dtm.ymin	1 x 1 double	Easting of first row of dtm.h to 1 metre resolution	m
dtm.xmax	1 x 1 double	Northing of last column of dtm.h to 1 metre resolution	m
dtm.ymax	1 x 1 double	Easting of last row of dtm.h to 1 metre resolution	m

Population Data

2.10 Due to computing limitations, it is not feasible to assess the entire UK data at once. Therefore, population points are split into assessment areas, the geographical boundaries of the areas used by Ofcom in the assessment process are given in Annex 1.

2.11 For each population assessment area population data is constructed into MATLAB structure array PC.

2.12 The PC structure array has fields; id, x, y, pop, nation, clutter, h, latitude and terrain which contain a value for each population point and sq which has a single value relating to the population assessment area. A description of PC data for m population points is shown in Table 2.2.

2.13 The clutter value relates to the environment of the population point. The mapping of the clutter values to environments is given in Table 2.1 of the 3G Coverage Obligation Verification Methodology document[1].

2.14 Each PC variable should be saved with the filename format 'xx_PC.mat' where xx is the population assessment area.

Table 2.2 Specification of PC variable

Field	Format	Description	Data Unit
PC.id	m x 1 cell	Postcode ID	
PC.x	m x 1 double	Easting to 1 metre resolution	m
PC.y	m x 1 double	Northing to 1 metre resolution	m
PC.pop	m x 1 double	No. of Population	
PC.nation	m x 1 cell	England, Northern Ireland, Scotland or Wales dependant on (x, y)	
PC.sq	string	Assessment area ID e.g. HP or SO_2	
PC.clutter	m x 1 double	Clutter category in the range 1 to 10	
PC.h	m x 1 double	Receiving antenna height, 1.5.	m
PC.latitude	m x 1 double	Latitude	degrees
PC.terrain	m x 1 double	Height of	m

Base Station Data

2.15 For each NGR square, base station data for that square and a 50 kilometre buffer zone is constructed into MATLAB structure array BS. This is done as part of the simulation process described in section 3.3.

2.16 The input network file, an Excel spreadsheet containing base station data with one row of data per base station site, is described in section 3 of the '3G Coverage Obligation Verification Data' document[3].

2.17 The name of the input network file should be defined within the simulation script 'Master_script.m' as NetworkName, as described in section 3.2.

2.18 The BS structure array has fields; id, x, y, freq, NumSec and terrain which contain a value for each base station. It also has fields; eirp, gain, azimuth, downtilt, H3dB, V3dB which contain values for each base station sector, and sq, network and MaxSec which have single values relating to the network and the NGR square. A description of BS data for n base station sites is shown in Table 2.3.

Table 2.3 Specification of BS

Field	Value	Description	Data Unit
BS.sq	string	NGR square	
BS.network	string	Name of 3G network	
BS.id	n x 1 double	Base station id	
BS.x	n x 1 double	Easting	m
BS.y	n x 1 double	Northing	m
BS.freq	n x 1 double	Frequency	MHz
BS.h	n x 1 double	Height of antenna	m
BS.NumSec	n x 1 double	Number of sectors	
BS.MaxSec	1 x 1 double	Maximum value of Number of sectors	
BS.eirp	n x MaxSec double	Sector eirp	dBm
BS.gain	n x MaxSec double	Sector antenna gain	dBi
BS.azimuth	n x MaxSec double	Sector azimuth	deg
BS.downtilt	n x MaxSec double	Sector downtilt	deg
BS.H3dB	n x MaxSec double	Sector horizontal 3 degree beamwidth	deg
BS.V3dB	n x MaxSec double	Sector vertical 3 degree beamwidth	deg
BS.terrain	n x MaxSec double	Terrain height	m

Section 3

Explanation of MATLAB code

3.1 The simulation code is split into three parts.

a) Processing of base station data into BS variables for each NGR square.

b) Calculation of path loss between all population points and their closest 20 base stations.

c) Monte Carlo simulation to gain SINR distributions for each population point which is assessed against the coverage threshold to determine if that point is served and the calculation of cumulative coverage until the 90% requirement is met.

3.2 In order to make the modelling easier to handle, a master script, ‘Master_script.m’ is provided to perform the data processing, path loss, SINR and coverage calculations in a single process. To run the master script users need to edit the script to define three variables:

- Network_Name – This is the name of network data excel spreadsheet without file path or file extension which is saved in the same folder as the Master_script.m file e.g. “Network_Name = ‘TestNetwork’;” where the input network file is ‘x:\3GCOV\TestNetwork.xlsx’.

- TerrainFilePath – the file path of the folder containing the dtm variables e.g. “TerrainFilePath = ‘x:\3GCOV\TerrainData\’;”.

- PC_path – the file path of the folder containing the BS variables, e.g. “PC_path = ‘x:\3GCOV\PopulationData\’;”.

3.3 Data in the input network file is processed by the ‘LoadBSData_fun.m’ and ‘terrP1144_function.m’ files in the ‘Data Process’ folder of the published 3G assessment model to create the required BS structure array variables.

3.4 The MATLAB simulation code for performing the path loss calculations is located in the folder ‘PathLoss_Hata’ using files ‘ExtendedHata_mat_freq.m’, ‘Hata2_precalculation.m’, and ‘PathLoss_Hata.m’ that are listed in Table 4.2.

3.5 In the path loss calculation, if the number of available base stations for a population point is below 20, only the available base stations within the corresponding NGR square, with buffer zone, are considered.

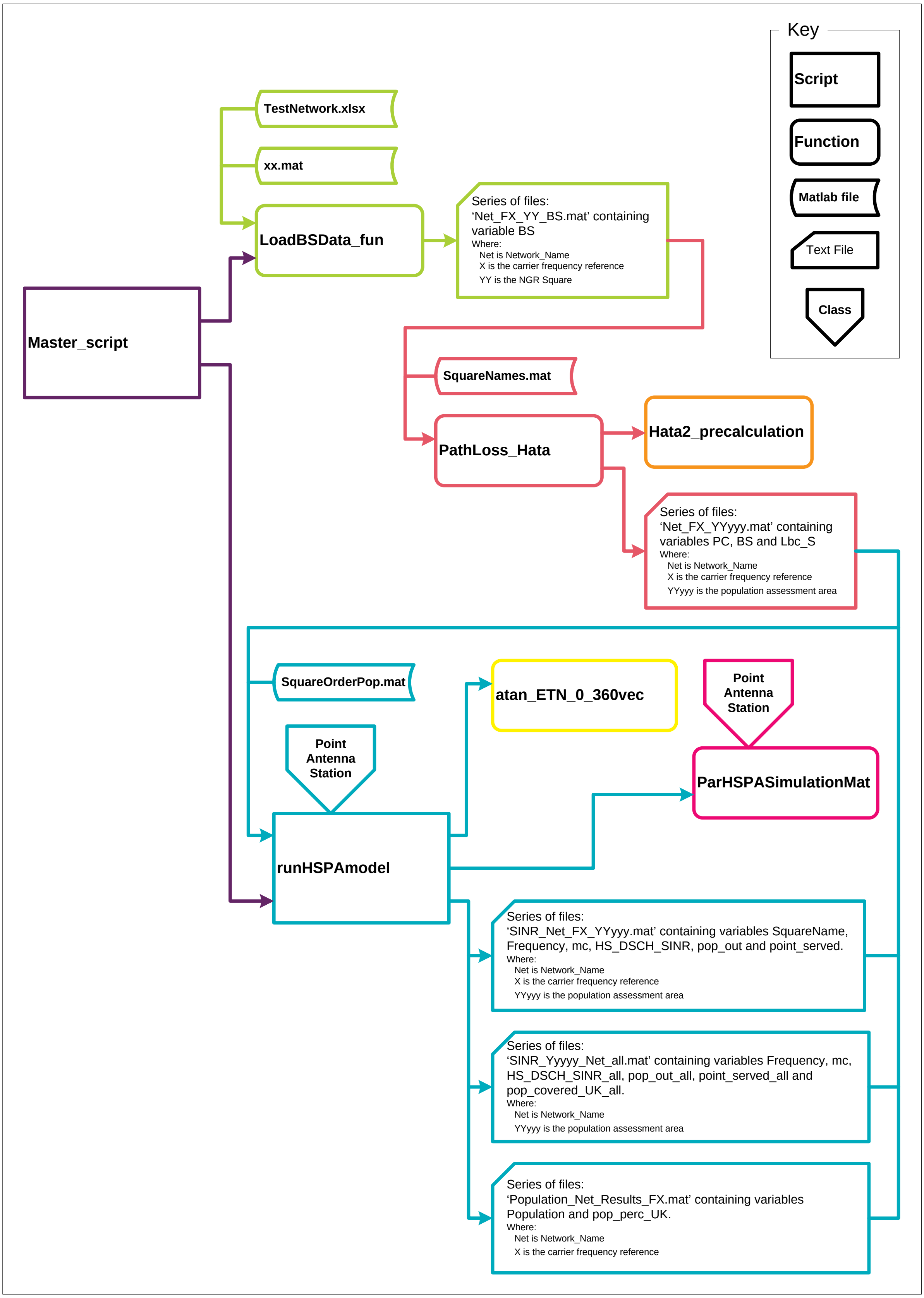
3.6 The MATLAB simulation code for performing the SINR and coverage calculation is undertaken within the main MATLAB script ‘runHSPAmodel.m’, all files relating to this calculation are contained in the folder ‘HSPA model’.

3.7 For each population assessment area in turn, using the pre-calculated path losses, along with PC and BS variables, the script ‘runHSPAmodel.m’ calls class file ‘Station.m’ to generate SINR levels for each population point.

3.8 The SINR results are compared to the coverage threshold and the population of the served points are summed to give total population covered taking account of all assessed population points. When the 90% coverage threshold is reached the simulation is stopped.

3.9 The relationships between scripts, functions, input files and output files are mapped in Figure 3.1.

Figure 3.1 Mapping of MATLAB files



Section 4

List of MATLAB files

4.1 Tables 4.1 to 4.5 outline the MATLAB code additional data files of the modelling tool.

Table 4.1 Class files

Class file name	Description
Antenna.m	Class to model antenna objects using a theoretical pattern based on that given in 3GPP 36.814 Annex A Table A.2.1.1-2
Point.m	Class defining a base class for all point like objects (i.e. locations)
Station.m	Class to calculate a (Monte Carlo) HSPA downlink performance to a selected population point. It takes an array of 20 (or less than 20) closest base stations and selects the maximum served power as wanted signal to calculate the SINR.

Table 4.2 Function files

Function file name	Description
atan_ETN_0_360vec.m	Function to calculate relative direction of population point with respect to base station. Start from east of true north, clockwise 0 to 360 degrees.
ExtendedHata_mat_freq.m	Function to calculates the path loss between points based on the Extended Hata model
Hata2_precalculation.m	Calculation of path loss based on Extended Hata propagation model. For each population point the 20 closest base stations are identified and the path loss is calculated.
Input_script.m	Function to pre-calculate path loss between every population point and the 20 closest base stations for all population assessment areas. For each population assessment area, base station data, population data and path loss are saved as input for SINR calculation.
LoadBSData_fun.m	Function to load base station data from spreadsheet, and process all base station to each NGR square.
ParHSPASimulationMat.m	Function to perform a (Monte Carlo) simulation of HSPA downlink performance. It takes an array of base station (objects of the Station class) and calculates the downlink HS-DSCH SINR (using the SINR method of the Station class).

PathLoss_Hata.m	Function to load BS and PC variables for each population assessment area in turn and use the Hata2_precalculation.m function to calculate and save path losses.
TerrP1144_function.m	Function to interpolate digital terrain map, and output the terrain height at population points and associated base stations. Requires input variable dtm.

Table 4.3 Script files

COV_SectorToSite_Script.m	Script to create input network file containing base station data in site format, as described in 'Clarification for 3G Coverage Obligation Verification Data' document[3], from an excel spreadsheet containing base station data in sector format.
Master_script.m	Script to call LoadBSData.m function and Input_script.m function for processing input data (base station, population point, and path loss). Please note: users have to define appropriate variables to successfully set up simulation.
runHSPAmodel.m	Main script to call code to generate SINR distributions and calculate coverage for each nation, as well as entire UK.

Table 4.4 Matlab data files

SquareNames.mat	Pre-defined data file lists 76 population assessment areas that are used in simulation. Some NGR squares are divided into smaller areas to reduce computation burden.
SquareOrderPop.mat	MATLAB data file lists the processing order from highest population density to lowest.
Squares.mat	MATLAB data file contains easting and northing figures for each NGR square.

Table 4.5 Excel template file

TestNetwork.xlsx	Excel template of required network data.

Annex 1

Population assessment area geographical definition

A1.1 The geographical boundaries of the population assessment areas are given in Table A1.1.

Table A1.1 Population Assessment Area Boundaries

Population Assessment Area	NGR square	Minimum Easting (m)	Maximum Easting (m)	Minimum Northing (m)	Maximum Northing (m)
HP	HP	400000	500000	1200000	1300000
HT	HT	300000	400000	1100000	1200000
HU	HU	400000	500000	1100000	1200000
HY	HY	300000	400000	1000000	1100000
HZ	HZ	400000	500000	1000000	1100000
NA	NA	0	100000	900000	1000000
NB	NB	100000	200000	900000	1000000
NC	NC	200000	300000	900000	1000000
ND	ND	300000	400000	900000	1000000
NF	NF	0	100000	800000	900000
NG	NG	100000	200000	800000	900000
NH	NH	200000	300000	800000	900000
NJ	NJ	300000	400000	800000	900000
NK	NK	400000	500000	800000	900000
NL	NL	0	100000	700000	800000
NM	NM	100000	200000	700000	800000
NN	NN	200000	300000	700000	800000
NO	NO	300000	400000	700000	800000
NR	NR	100000	200000	600000	700000
NS_1	NS	200000	260000	600000	700000
NS_2		260000	300000	600000	700000
NT	NT	300000	400000	600000	700000
NU	NU	400000	500000	600000	700000
NV	NV	0	100000	500000	600000

Population Assessment Area	NGR square	Minimum Easting (m)	Maximum Easting (m)	Minimum Northing (m)	Maximum Northing (m)
NW	NW	100000	200000	500000	600000
NX	NX	200000	300000	500000	600000
NY	NY	300000	400000	500000	600000
NZ_1	NZ	400000	500000	550000	600000
NZ_2		400000	500000	500000	550000
SA	SA	0	100000	400000	500000
SB	SB	100000	200000	400000	500000
SD_1	SD	300000	420000	400000	500000
SD_2		300000	400000	400000	420000
SE_1	SE	400000	500000	440000	500000
SE_2		400000	430000	400000	440000
SE_3		430000	500000	400000	440000
SH	SH	200000	300000	300000	400000
SJ_1	SJ	300000	400000	390000	400000
SJ_2		300000	360000	300000	390000
SJ_3		360000	300000	400000	390000
SK_1	SK	400000	500000	365000	400000
SK_2		400000	450000	300000	365000
SK_3		450000	500000	300000	365000
SM	SM	100000	200000	200000	300000
SN	SN	200000	300000	200000	300000
SO_1	SO	300000	400000	250000	300000
SO_2		300000	200000	400000	250000
SP_1	SP	400000	500000	280000	300000
SP_2		400000	450000	200000	280000
SP_3		450000	500000	200000	280000
SR	SR	100000	200000	100000	200000
SS	SS	200000	300000	100000	200000
ST_1	ST	300000	400000	170000	200000
ST_2		300000	400000	100000	170000
SU_1	SU	400000	500000	170000	200000
SU_2		400000	460000	100000	170000
SU_3		460000	500000	100000	170000
SV	SV	0	100000	0	100000

Population Assessment Area	NGR square	Minimum Easting (m)	Maximum Easting (m)	Minimum Northing (m)	Maximum Northing (m)
SW	SW	100000	200000	0	100000
SX	SX	200000	300000	0	100000
SY	SY	300000	400000	0	100000
SZ	SZ	400000	500000	0	100000
TA	TA	500000	600000	400000	500000
TF	TF	500000	600000	300000	400000
TG	TG	600000	700000	300000	400000
TL_1	TL	500000	600000	230000	300000
TL_2		500000	600000	200000	230000
TM	TM	600000	700000	200000	300000
TQ_1	TQ	500000	540000	185000	200000
TQ_2		450000	600000	170000	200000
TQ_3		527000	540000	160000	185000
TQ_4		500000	527000	160000	185000
TQ_5		500000	540000	100000	160000
TQ_6		540000	600000	100000	170000
TR	TR	600000	700000	100000	200000
TV	TV	500000	600000	0	100000