Smith institute
for Industrial Mathematics and System Engineering

Balancing Supply and Demand for Radio Frequency Spectrum

Jakob Blaavand

ISMOR36, 24 July 2019

Coca-Cola
EUROPEAN PARTNERS
TESCO
AIRBUS
Mondelēz
International
EDF
ENERGY
nationalgrid
FCC
vodafone

What problems do we work on?

Forecasting

Optimisation

AI

Auditing

How do we tackle them?

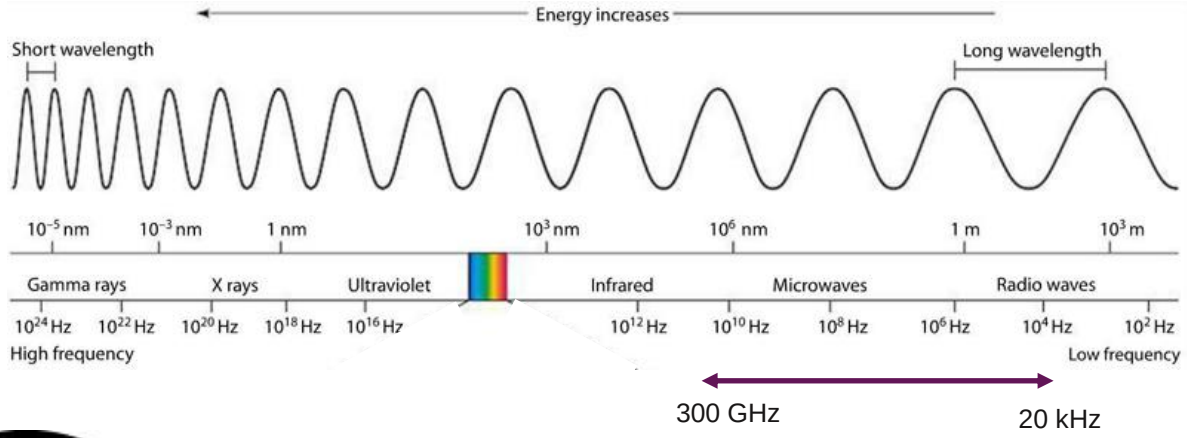
Data analytics

Model building

Algorithms

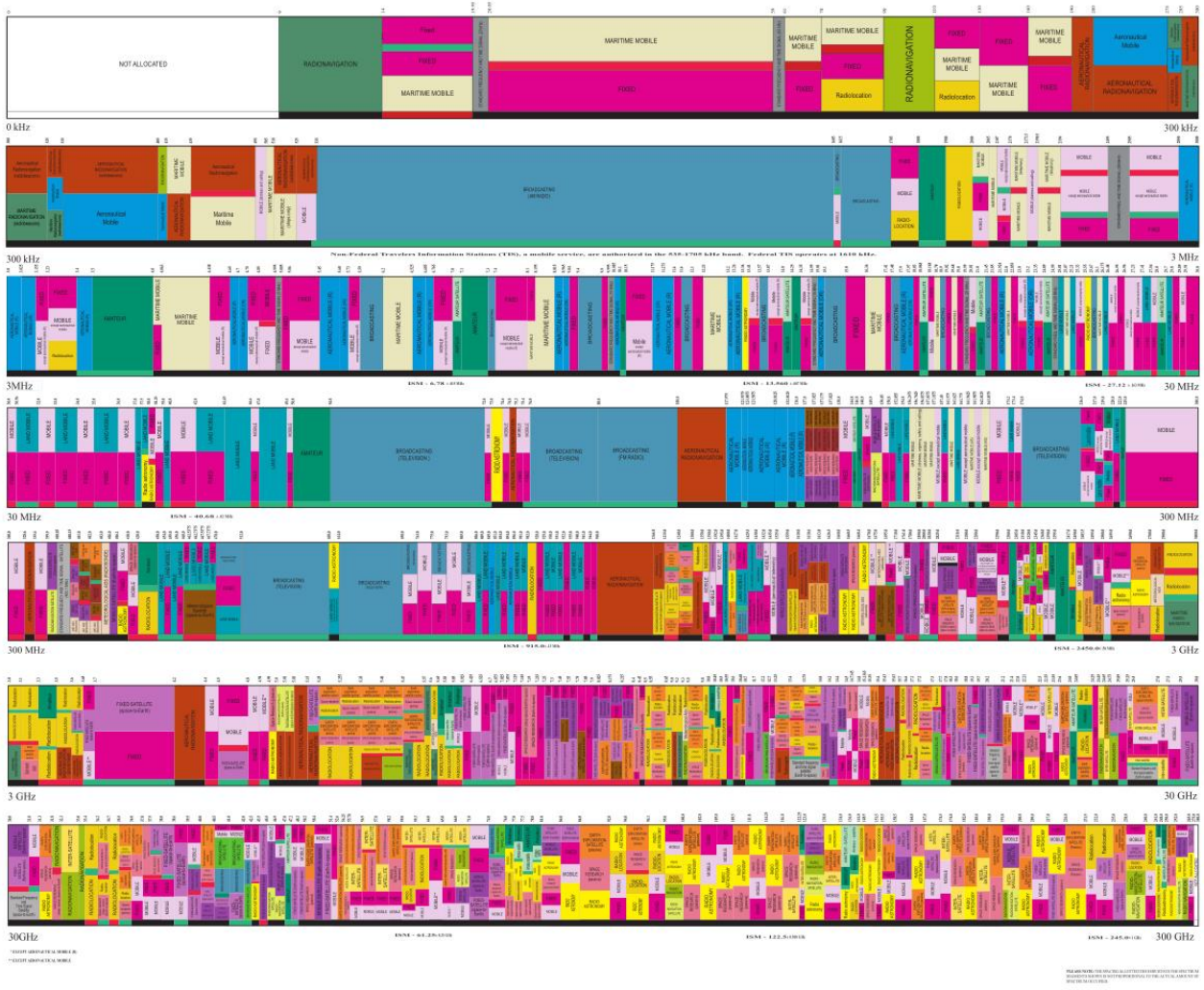
Integration

USES OF RADIO WAVES IN COMMUNICATION


Energy increases
Short wavelength
Long wavelength
10^{-5} nm
10^{-3} nm
1 nm
10^{3} nm
10^{6} nm
1 m
10^{3} m
Gamma rays
X rays
Ultraviolet
Infrared
Microwaves
Radio waves
10^{24} Hz
10^{22} Hz
10^{20} Hz
10^{18} Hz
10^{16} Hz
10^{12} Hz
10^{10} Hz
10^{8} Hz
10^{6} Hz
10^{4} Hz
10^{2} Hz
High frequency
Low frequency
300 GHz
20 kHz

UNITED STATES FREQUENCY ALLOCATIONS

THE RADIO SPECTRUM



RADIO SERVICES COLOR LEGEND

- AERONAUTICAL MOBILE
- AERONAUTICAL MOBILE SATELLITE
- AERONAUTICAL RADIONAVIGATION
- AMATEUR
- AMATEUR SATELLITE
- BROADCASTING
- BROADCASTING SATELLITE
- EARTH EXPLORATION SATELLITE
- FIXED
- FIXED SATELLITE
- INTER-SATELLITE
- LAND MOBILE
- LAND MOBILE SATELLITE
- MARITIME MOBILE
- MARITIME MOBILE SATELLITE
- MARITIME RADIONAVIGATION
- METEOROLOGICAL
- METEOROLOGICAL SATELLITE
- MOBILE
- MOBILE SATELLITE
- RADIO ASTRONOMY
- RADIODETERMINATION SATELLITE
- RADIOLOCATION
- RADIOLOCATION SATELLITE
- RADIONAVIGATION
- RADIONAVIGATION SATELLITE
- SPACE OPERATION
- SPACE RESEARCH
- STANDARD FREQUENCY AND TIME SIGNAL
- STANDARD FREQUENCY AND TIME SIGNAL SATELLITE

ACTIVITY CODE

- FEDERAL EXCLUSIVE
- FEDERAL/NON-FEDERAL SHARED
- NON-FEDERAL EXCLUSIVE

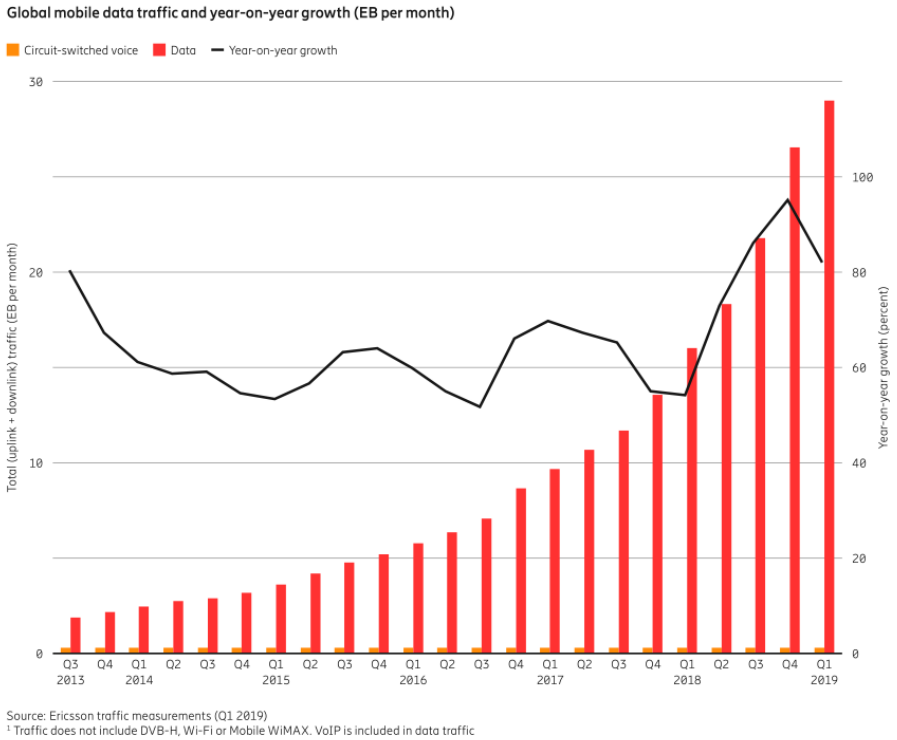
ALLOCATION USAGE DESIGNATION

SERVICE	EXAMPLE	DESCRIPTION
Primary	FIXED	Capital Letters
Secondary	Mobile	1st Capital with lower case letters

U.S. DEPARTMENT OF COMMERCE
National Telecommunications and Information Administration
Office of Spectrum Management

JANUARY 2016

Global data traffic



Source: Ericsson traffic measurements (Q1 2019)
[1] Traffic does not include DVB-H, Wi-Fi or Mobile WiMAX. VoIP is included in data traffic

Source: Ericsson Mobility Report 2019

40 MHz of MOD spectrum

£205,000,000 in April 2018

O_2 (Telefonica)

Reorganise static spectrum assignments

MHz

Constraints

MHz

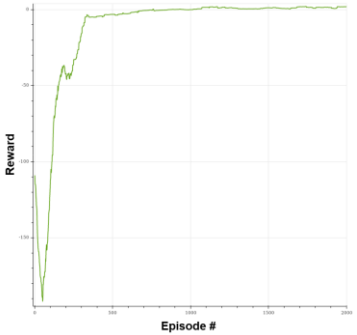
MHz

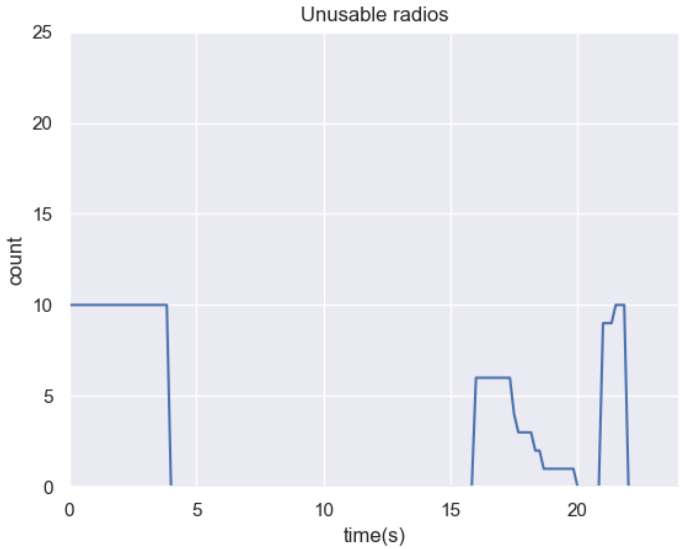
Defence and Security Accelerator

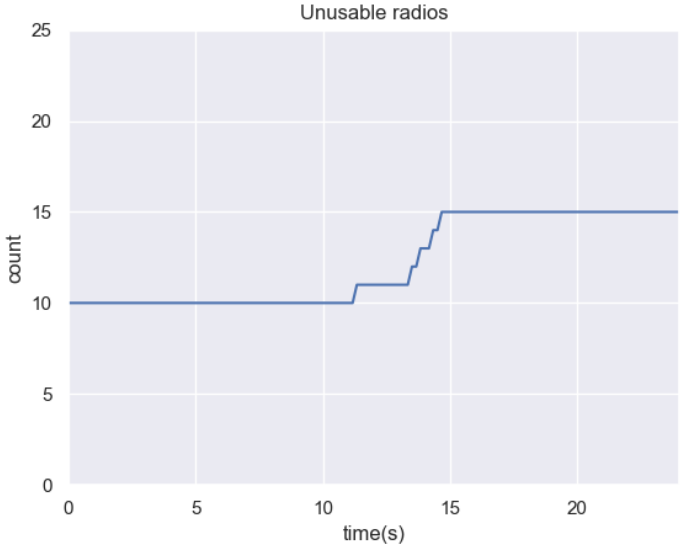
The Invisible Battlespace

How can UK Defence take a radically different approach to conducting operations effectively across / within the Electromagnetic Environment, in this increasingly Congested and Contested environment?

AI Reinforcement Learning
for interference protection and channel assignment

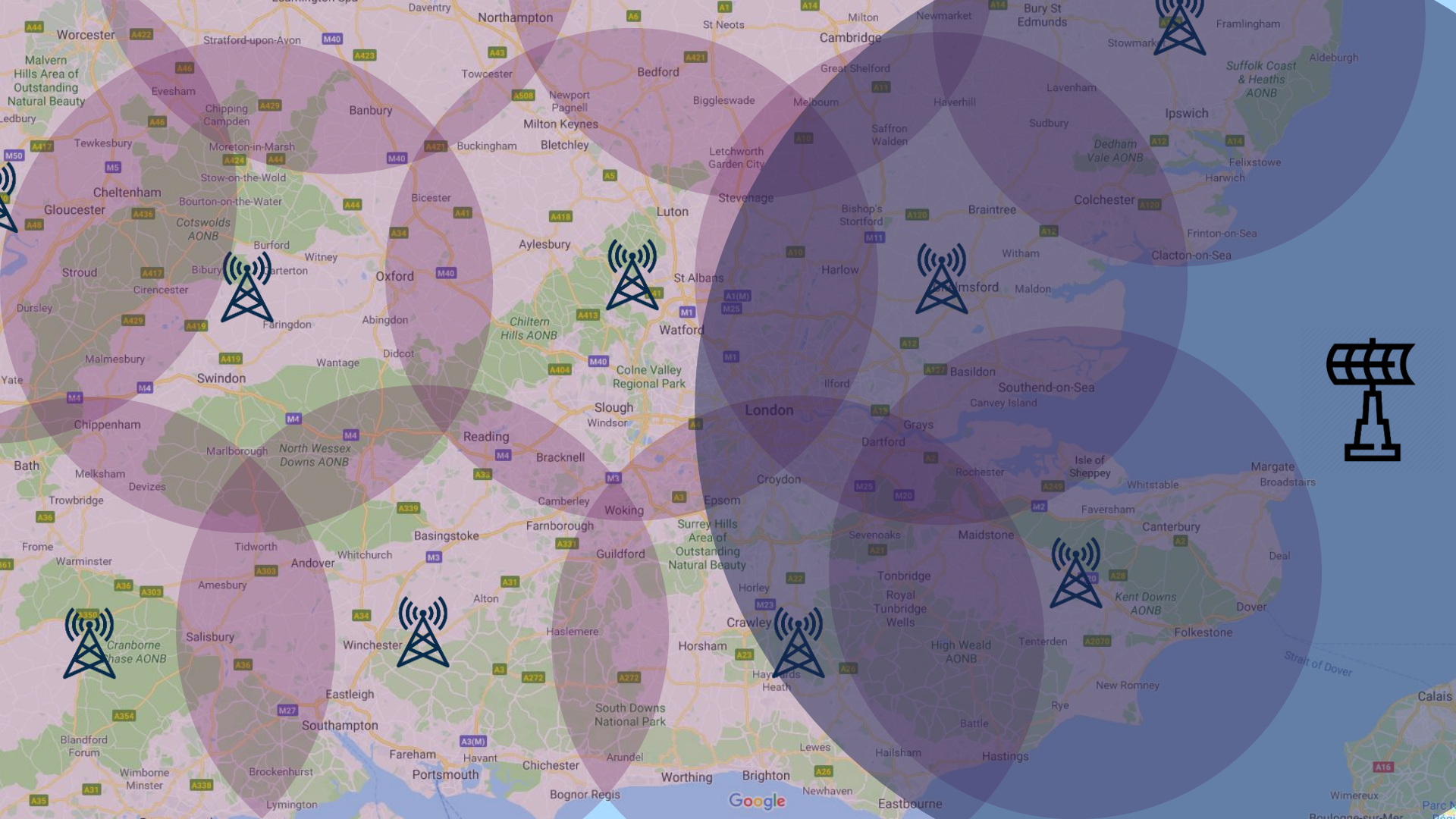



Unusable radios
count
time(s)
0
5
10
15
20
25


Unusable radios
count
time(s)
0
5
10
15
20
25

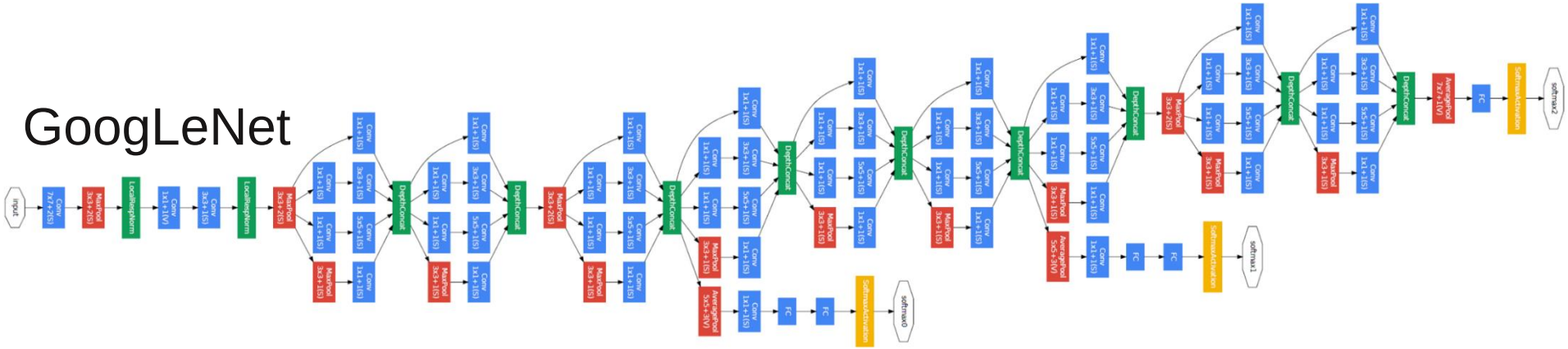
SPECTRUM
COLLABORATION
CHALLENGE
DARPA
Preliminary Event 2
AWARDS
SPECTRUM
COLLABORATION
CHALLENGE
SPECTRUM
COLLABORATION
CHALLENGE

Spectrum Sensing Situational Awareness

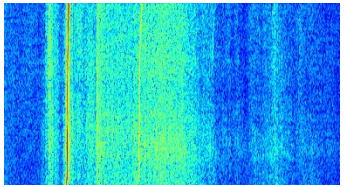

Worcester
Malvern Hills Area of Outstanding Natural Beauty
Stratford-upon-Avon
Daventry
Northampton
St Neots
Milton
Cambridge
Newmarket
Bury St Edmunds
Framlingham
Stowmarket
Aldeburgh
Suffolk Coast & Heaths AONB
Evesham
Chipping Campden
Banbury
Towcester
Bedford
Great Shelford
Newport Pagnell
Milton Keynes
Biggleswade
Melbourn
Haverhill
Lavenham
Ipswich
Sudbury
Tewkesbury
Moreton-in-Marsh
Buckingham
Bletchley
Saffron Walden
Letchworth Garden City
Dedham Vale AONB
Felixstowe
Harwich
Stow-on-the-Wold
Cheltenham
Gloucester
Bourton-on-the-Water
Bicester
Stevenage
Luton
Bishop's Stortford
Braintree
Colchester
Cotswolds AONB
Burford
Witney
Aylesbury
Frinton-on-Sea
Clacton-on-Sea
Stroud
Bibury
Carterton
Oxford
St Albans
Harlow
Witham
Chelmsford
Maldon
Cirencester
Dursley
Faringdon
Abingdon
Chiltern Hills AONB
Watford
Malmesbury
Wantage
Didcot
Colne Valley Regional Park
Basildon
Southend-on-Sea
Yate
Swindon
Ilford
Canvey Island
Slough
Windsor
London
Grays
Chippenham
Reading
Dartford
Marlborough
North Wessex Downs AONB
Bracknell
Isle of Sheppey
Margate
Broadstairs
Bath
Melksham
Devizes
Croydon
Rochester
Whitstable
Trowbridge
Camberley
Woking
Epsom
Faversham
Canterbury
Basingstoke
Farnborough
Surrey Hills Area of Outstanding Natural Beauty
Sevenoaks
Maidstone
Frome
Tidworth
Whitchurch
Guildford
Deal
Warminster
Andover
Amesbury
Tonbridge
Royal Tunbridge Wells
Kent Downs AONB
Dover
Alton
Horley
Crawley
Folkestone
Salisbury
Winchester
Haslemere
Horsham
High Weald AONB
Tenterden
Cranborne Chase AONB
Strait of Dover
Eastleigh
Haywards Heath
New Romney
Calais
Southampton
South Downs National Park
Rye
Battle
Blandford Forum
Fareham
Havant
Lewes
Hailsham
Hastings
Wimborne Minster
Brockenhurst
Portsmouth
Chichester
Arundel
Worthing
Brighton
Newhaven
Lymington
Bognor Regis
Eastbourne
Wimereux
Google

Fine-tune trained classifiers

GoogLeNet



Spectrogram



National Institute of Standards and Technology
U.S. Department of Commerce

3.5 GHz

Data availability is the challenge

SUMMARY

- Radio spectrum is a limited resource
- More efficient use is needed
- Reorganise existing allocations more efficiently
- Dynamic assignments or sharing rather than static assignments
- Tech can help with it all, e.g. through optimisation or AI

Jakob Blaavand

jakob.blaavand@smithinst.co.uk

+44 (0)7917 155421

Smith institute
for Industrial Mathematics and System Engineering