DAFNI PILOT 1: Digital Communications Models: Mobile 5G and Fixed Broadband Network

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Glossary

Item	Definition
Containers	Containers allow a developer to package up an application with all the parts it needs, such as libraries and other dependencies, and ship it all out as one package. Docker is commonly used to run containers.
Kubernetes (k8s)	Kubernetes is an open-source system for automating deployment, scaling and management of containerized applications.
Docker	Docker is a tool designed to make it easier to create, deploy and run applications by using containers.
Docker-compose	It is a tool for defining and running multiple container Docker applications.
NIMS	National Infrastructure Modelling System, a component of the DAFNI platform.

Introduction to DAFNI Pilots

DAFNI will provide the National Platform to satisfy the computational needs in support of data analysis, infrastructure research and strategic thinking for the UK's long term planning and investment needs. The platform will support academic research that is aiming to provide the UK with a world leading infrastructure system that is more: efficient, reliable, resilient and affordable. DAFNI will support big data analytics, simulation, modelling and visualisation.

DAFNI Pilots are series of projects that run alongside the DAFNI core platform development and seek to take existing established infrastructure codes and implement them in a Cloud based environment that emulates the expected future DAFNI system. DAFNI pilot projects are submitted by the members of DAFNI community and projects are chosen based on proposers' resource availability, benefits to DAFNI such as validating DAFNI's components, stress testing the DAFNI hardware etc. Each pilot project typically runs for 3-6 months and is supported by the DAFNI pilot team, consisting of 2-3 software developers. This will enable the following benefits to the DAFNI and its community:

- Demonstrate the capabilities of the DAFNI infrastructure.
- Feed the community requirements into improving and maturing the DAFNI infrastructure.
- Provide early access for the modellers to test their models on the DAFNI platform.
- Provide additional access to infrastructure models that may form part of the DAFNI service.
- Allow exploration of visualisation techniques useful to infrastructure modellers.
- Highlight typical data set requirements for infrastructure research.

Overview of Digital Communications Modelling

In this new digital age, devices are interconnected and there is an ever growing need for reliable, scalable and responsive internet networks for devices to communicate. There are three main modes for delivering internet connections to the devices:

- Fixed Broadband, dependent on the physical network connecting premises.
- Mobile communications, dependent on the location and technology of mobile phone towers.
- Satellite Communications, not currently part of this modelling system.

The fixed broadband network is crucial for business and home communications. Modelling the demands of the fixed broadband network is essential to allow decision makers to make the right technology choices and investments for the design and construction of an efficient infrastructure that meets the demands of future fixed broadband communications.

Mobile communication is key to delivering smart infrastructure and cities, as well as providing an alternative to fixed broadband connections that reach beyond the expected future mobile bandwidth requirements as new technologies, such as 5G, are rolled out. The Principle Investigator for this Pilot is Edward Oughton from the University of Oxford who developed both the fixed broadband and mobile communication models. These use a range of models for future communication requirements and possible technology deployments on the current UK infrastructure to estimate costs and effectiveness of different strategies in meeting demand over the next 10-20 years.

Analysis of Software

Mobile communications model

The mobile model utilises existing cell and site locations, capacity lookup tables, population data, network coverage and demand forecasts. The model uses parameters for the start and end date as well as the population scenario, infrastructure deployment strategy and user demand scenario. The model simulates the impact of network upgrades needed to meet coverage obligations and budget constraints and finally outputs the intervention decisions, system capacity information and budget spend for each year.

The calculation of demand and required upgrades is straightforward and not computationally demanding, so runs well as a single Docker image within the DAFNI compute cloud. Docker was introduced as a means of containerising the model which ensured that it could be run in isolation as a decoupled process. This also made it easier to support multiple instances running in parallel to investigate how demand and cost depend on the selected models.

Fixed broadband Model

The fixed broadband model utilises spatial data on residential and commercial premises, telephone exchanges and cabinet location postcodes. Using this data, the model, spatially locates cabinet and distribution point locations to create a full 35 million node broadband network for Britain. The model also requires the initial demand, capacity, universal service targets and intervention strategy inputs to generate a set of numerical geospatial outputs, including intervention decisions, system capacity information and budget spend.

Challenges

Each model is trying to address the modelling of digital communications in UK. The key requirements for both models are being able to try out different technology selection scenarios, investment scenarios and population growth scenarios. Each scenario selection enables the model to output network capacity projection, investment cost and network demand results related to digital communication in user-friendly visualisations.

Mobile Communications Model

In contrast to the fixed broadband model, the mobile communication model does not depend on licensed datasets allowing for a straightforward integration onto the DAFNI infrastructure. Therefore, the main challenge for this model was building an end-to-end system from scratch which could support the model as software as a service (SaaS) and be generic enough to also be used for future models. This work included designing the system, implementing the APIs, creating the databases, integrating with Kubernetes and developing the user interface. As there was no pre-existing user interface for this application, the pilot team had to come up with the design of the interface and implement it. Given that the number of mobile towers incorporated into the model is nearly 200,000 the visualisation function allows the data to be displayed on a map for the users to interactively explore the information that relates to mobile tower metadata. The other visualisation challenge is to display the results data with local authority boundary.

Fixed Broadband Model

The major challenge with porting of fixed broadband model onto DAFNI infrastructure was getting the datasets required for the model onto DAFNI. The initial model had dependency on closed licensed datasets that the DAFNI team cannot use. To allow a proof of concept the Principle Investigator (PI) was able to generate an approximate synthetic data set to allow an adequate demonstration of this model. Unfortunately, the pre-processing steps for simulating this synthetic data are very compute-intensive and therefore can take days to run. However, the PI was able to provide a much smaller test dataset which was used to port the model onto DAFNI. With this smaller dataset, the model is trivial to run compared to what it would be with the full dataset.

Outcomes

The key outcome of this pilot project was the provision of a Software as a Service (SaaS) implementation for both models and a common interface for executing the digital communication models. The main features of the service are:

1. A web application with capabilities to run the model using a selected set of scenarios and visualise the results for further analysis. This allows a user of the model to easily view and interact with results with zero installation and minimal local computing requirements. A web browser interface allows the bulk of the computation to be performed on the DAFNI resources. Since all of the results are stored on the server side, there is also no need for the user to copy any data to their machine although there is the option for them to do so if they wish.
2. Interactive visualisation that includes map and graph plots visualisation for model results exploration, comparison of results with other model runs.
3. Interface to run single or multiple model runs for different scenarios.

A typical view of the GUI to submit jobs is shown below. This is for the mobile communications case. The user is able to select scenarios and submit jobs to simulate these conditions over the required time period. The GUI automatically updates to show the progress of the deployed jobs, which can then be selected and viewed in the visualisation section.

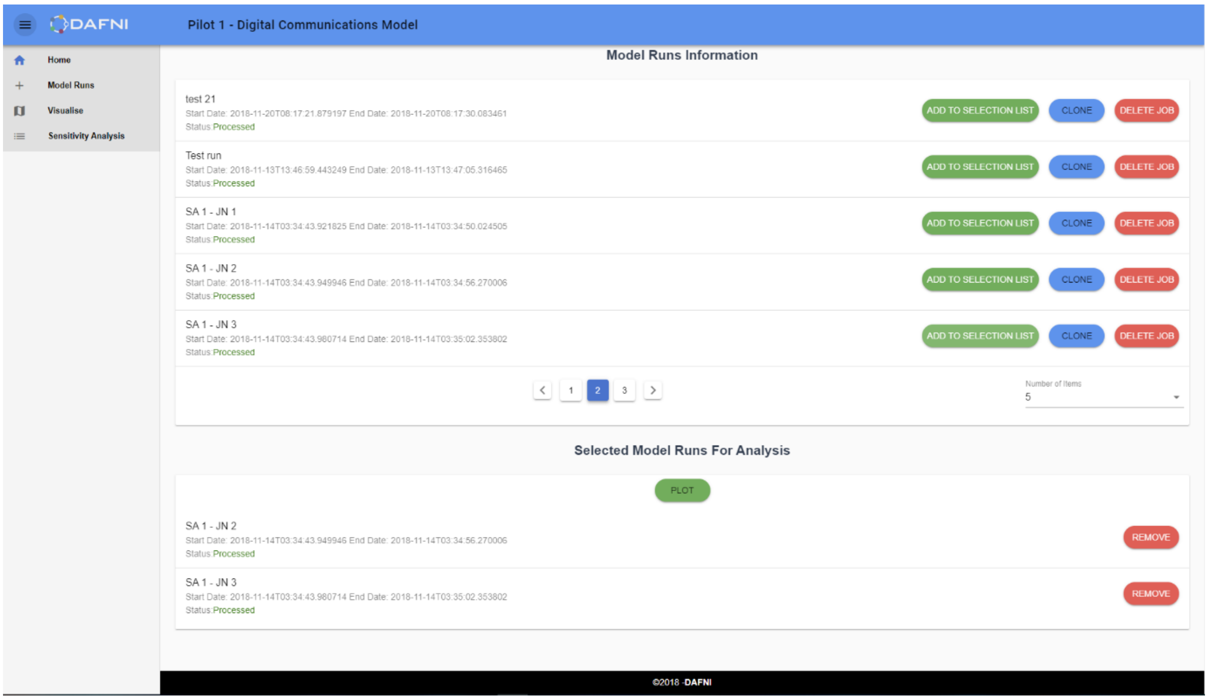

Figure - 1

An example of the visualisation is shown in figure 2a for the predicted population growth in two local authority areas as a function of time. Figure 2b shows the communication towers in one of these regions.

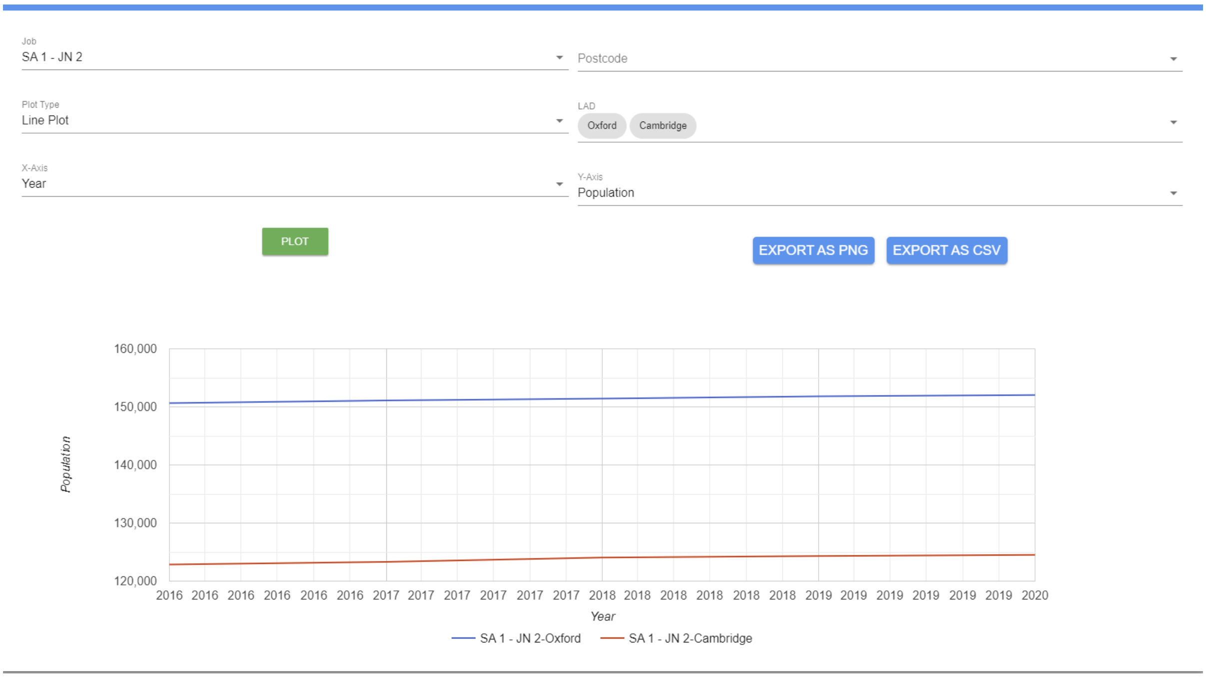

Figure – 2a

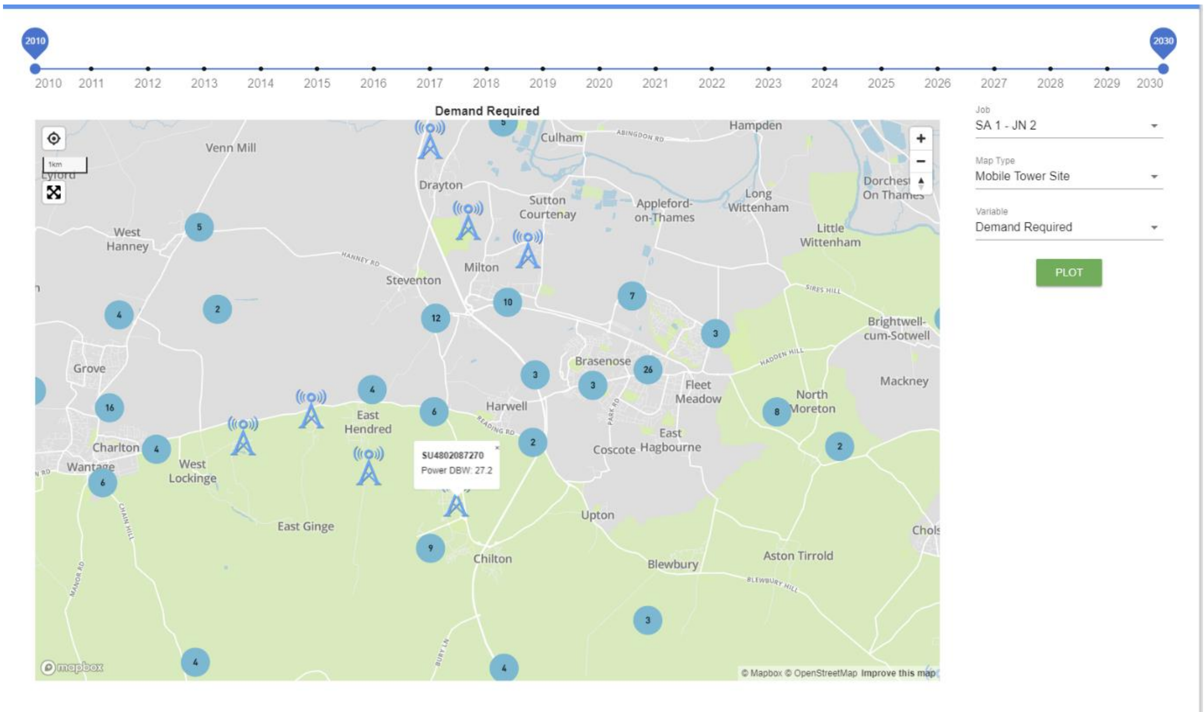

Figure – 2b

Benefits

The key benefits arising from this project are as follows:

a. Integration of models onto the DAFNI infrastructure and development of a user interface to interact with the models.
b. Validation of simple visualisation requirements for the DAFNI and execution environments requirements for the models.

c. Establishment of a simple job queuing system that enables multiple jobs to be executed in the Kubernetes infrastructure that is intended to manage the DAFNI workload in terms of managing the run order of compute-intensive tasks.
d. The importance of ensuring that access to suitable data sets is identified prior to Project initiation. The PI now has the digital communication models ported onto DAFNI.
e. Now that both models have been fully containerised, enabling System of Systems modelling across other infrastructure datasets will be much more readily achieved.
f. Visualisation interfaces developed as part of this pilot can be reused for similar models.

Lessons Learned

Platform

- Much was learned about producing a generalised "job manager" system which can queue up and execute jobs. This work will be very useful when developing the NIMs as it promises to be a very similar system.
- The pilot team's work using Docker is already becoming very useful to the platform team. Since they are intending to set up a working end-to-end system, the pilot team has shared much of their gained docker-compose knowledge to enable them to do this much more easily.
- The APIs produced for this pilot are all fully tested with a Django test suite. The pilot team will be looking to share their knowledge of this with the platform team as they start to write tests for their APIs.
- When working with Kubernetes, the pilot team gained a lot of knowledge about the CI pipeline and even have a low level understanding of the Kubernetes CLI and python library. The platform team will inevitably run into the same issues as the pilot team had and they should therefore be much easier to resolve.
- The user-interface components, visualisation components and interface testing framework used in this pilot helped standardising the platform interface components. Some of these components will be part of the platform user-interface library.

Pilot

- One key take away from this pilot was the readiness and availability of datasets and licenses associated with the model. A lot of time was spent in figuring out license restrictions on datasets to get the model ready to be used on DAFNI.
- The pilot team also learned that communication with the PI was imperative. Weekly meetings were organised with Edward Oughton to give updates from both sides as well as to talk through any blockers of the project. It was also useful to create a Slack workspace for the project so that those working on the project could communicate much more easily.
- Creating modules of the system to be as generic as possible will make future pilots much easier. At the start, the job manager implementation was very specific to this pilot but much of the code was eventually re-used for pilot 2. Going forward, the pilot team will endeavour to make all modules of the system generic enough to be re-used.

Pilot Extensions

The current model runs with a fixed set of scenarios; the extension to broader investigations is not yet implemented but can be readily incorporated, enabling users to create new scenarios and run the models with sensitivity analysis.

The current digital communication model SaaS doesn’t have integration with user authentication and authorisation. This will be developed as part of the DAFNI platform.

The fixed broadband model requires a pre-processing step to generate a broadband network model covering whole of UK which takes more than a day to generate. This process has not been migrated to DAFNI in this pilot. There is scope for this to be migrated to the compute core of DAFNI in the future.