# cdcam: Cambridge Digital Communications Assessment Model

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## Summary

Digital connectivity is an essential infrastructure service, as more and more people and machines are connected to the internet. Mobile internet access is one of the cheapest ways to connect wirelessly, and new technologies (particularly 5G) can offer access speeds which can rival fixed broadband connections. Successive generations of mobile telecommunication technologies (3G-5G) have increased data transmission rates and reduced latency. However, user-generated data traffic has been growing exponentially over the past decade which is concerning for both mobile network operators and policy decision-makers, with future growth forecasts indicating this trend is likely to continue (Oughton et al., 2018).

The Cambridge Digital Communications Assessment Model (cdcam), is a decision-support model which quantifies the performance of digital infrastructure strategies for mobile digital communications. cdcam models the performance of 4G and 5G technologies as they roll-out over space and time, given a set of exogenous population and data growth scenarios, and potential deployment strategies.
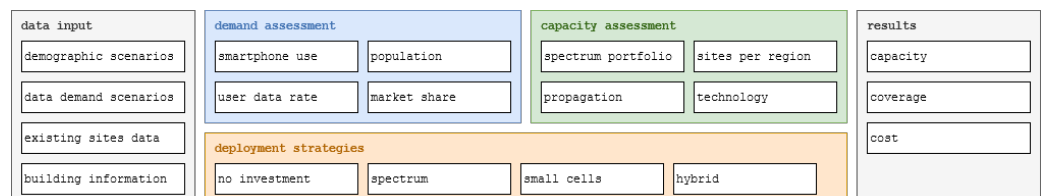
**Figure 1:** Framework for capacity/demand/strategy assessment

The simulation approach can be used nationally, or for a specific sub-regional area. The same decision-support modelling approach is taken as in the field of telecommunication regulation, where the Long-Run Incremental Cost is estimated for a representative hypothetical mobile network operator.

## Statement of Need

Every decade a new generation of cellular technology is standardised and released. Increasingly, given the importance of the Internet of Things, Industry 4.0 and Smart Health applications, both governments and other digital ecosystem actors want to understand the costs associated with digital connectivity. However, there are very few open-source tools to help simultaneously understand both the engineering and cost implications of new connectivity technologies such as 5G. Hence, there is a key research need for this software.

Governments currently have a strong interest in 5G, with many making it a cornerstone of their industrial strategy. But there remain many coverage issues associated with basic 2G-4G mobile connectivity, particularly in rural areas. Market-led deployment approaches have many benefits, but as the delivery of connectivity in low population density areas becomes less viable, the market will at some point fail to deliver the infrastructure to support these necessary services. Software tools can help to provide the evidence base for policy and government to develop effective strategies to address this issue.

Additionally, while many large mobile network operators have their own in-house technoeconomic network planning capabilities, smaller operators do not. As a result, engineering analysis and business case assessment often take place as separate steps, rather than as an integrated process. This is another key use case for `cdcam` as engineers and business analysts at smaller operators could use the software to assess the costs of delivering connectivity to target areas.

## Uniqueness

The software is unique because unlike the industry-standard Long-Run Incremental Cost modelling approach, which is predominantly spreadsheet-based, the `cdcam` explicitly models the spatio-temporal roll-out of a new generation of cellular technology (e.g. 5G roll-out).

Such a framework allows users to explore how different infrastructure strategies based on heterogeneous technologies perform in terms of the capacity provided, the degree of population coverage, and the necessary investment costs.

## Spatial Units

Three types of spatial units are used in the model, including sites (points), lower layer statistical units, treated here as postcode sectors (polygons), and upper layer statistical units, treated here as local authority districts (polygons). The justification for using two layers of polygon statistical units is that it allows local areas to be upgraded using a high level of spatial granularity (n=9000), but then provides a level of aggregation for reporting results in a more manageable way (n=380).

## Technologies and Deployment Strategies

There are three main ways to enhance the capacity and coverage of a wireless network: improving the spectral efficiency; adding more spectrum; and building more sites.

An analogy with a highway can be a useful way to explain these techniques. Improving the spectral efficiency enables you to fit more bits per Hertz on a radio wave, which is analogous to more vehicles per lane on a highway. Adding more spectrum provides you with more lanes on the highway, in which to fit more vehicles. Finally, building more sites can enable greater spatial reuse of existing spectrum, which is analogous to increasing the density of roads in an area, reducing the level of congestion.

`cdcam` is capable of testing all three technology options by: upgrading sites to 4G, or from 4G to 5G, hence improving spectral efficiency; adding more spectrum bands, for either 4G (0.8 and 2.6 GHz), or 5G (0.7, 3.5, 26 GHz); and building more sites (a Small Cell layer).

Each of these technology options is then grouped into a set of strategies, including: No Investment, Spectrum Integration, Small Cells, Spectrum integration and Small Cells (hybrid).

### Cellular capacity estimation

A common way to estimate the system capacity of a cellular network is via stochastic geometry methods. In this model we make use of another open-source Python library with stochastic geometry capabilities, the Python Simulator for Integrated Modelling of 5G, `pysim5G` (Oughton et al., 2019b). Using `pysim5G`, a capacity lookup table is generated using a set of simulations for each frequency band, for inter-site distances ranging from 400m to 30km. This lookup table is provided with the `cdcam` release in the data folder.

### Applications

`cdcam` has already been used to test the capacity, coverage and cost of 5G infrastructure in Britain (Oughton & Frias, 2018; Oughton et al., 2018) and the Netherlands (Oughton et al., 2019a).

The model is one of several infrastructure simulation models being used in ongoing research as part of the ITRC Mistral project to analyse national infrastructure systems-of-systems, using scenarios of population change generated by `simim` (Smith, Russell, & Usher, 2019) and connected by a simulation model coupling library, `smif` (Usher & Russell, 2019).

### Acknowledgements

## References

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