An overview of Eboracum: Innovative adaptive signal control in York

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Abstract:

The DfT funded Eboracum project in the city of York explores the use of new vehicle centric data sources in better signal setting. These data sources are primarily floating vehicle data supplied by INRIX and wifi MAC addresses harvested using IDT's roadside beacons. A smartphone app developed by the Ian Routledge Consultancy uses the OBD2 port on the vehicle to provide additional data such as emissions faults in a proof of concept. In a sister project, Middlesex University are testing ITS-G5 beacons and in vehicle units to further compare the properties of the various data sources.

Once the vehicle/user-based journey data has been collected, in an anonymous and GDPR-compliant way, it is used to derive and predict journey times and, hence, to build new signal plans. The project will then use the data to trigger plan changes, and changes in signal control strategy, evaluated against SCOOT as a baseline.

Potential future tasks within COYC's new STEP project will expand on the learning from Eboracum and include the use of individual vehicle data to develop trajectories of vehicles approaching signals and real time control.

Introduction

York is a vibrant city with much commuter traffic and many tourist visitors. The traffic network is constrained by its historic layout, and suffers from the increasing congestion that accompanies economic growth. Hence, City of York Council (COYC) has invested in tools like park and ride and enhanced electric buses, as well as traffic control systems. COYC also wants to make the best of opportunities in co-operative ITS (C-ITS) from vehicle-based data. But like many UK authorities, the evidence base for investment is not yet in place and the practicalities are unknown.

Hence this scheme, funded by DfT under the C-ITS programme, aims to understand if and how probe vehicle data from both beacon and cellular approaches can improve a typical UK commuter corridor for all road users, including park and ride buses. C-ITS technology is important as it could provide new tools for polices such as emissions control, improve flexibility and responsiveness of traffic signals and provide better monitoring of traffic, as well as reducing whole life cost and enabling York to make the most of limited resources.

Current problems include congestion, which leads to delays and unreliability and adds to emissions. York is significant for employment, commerce and tourism and so ensuring network performance is essential. York pioneered promotion of public transport, walking and cycling in delivering and sustaining growth and access whilst protecting the environment. Efficient operation of road space includes providing capacity for an attractive and efficient bus service, supporting park and ride and dedicating road space for safe cycling and walking.

COYC has considered options like UTOPIA and SCOOT but does not want to invest in an infrastructure system when data from vehicles is emerging quickly. This project allows us to retain the current UTC system as a central platform for monitoring and controlling signals at the same time as utilising C-ITS to provide new tools to improve network performance for the benefit of all. The expected benefits/outcomes are understanding which probe-based signal strategies work best, costs and benefits of integration, how UK citizens embrace co-operative technology and above all, help for other UK authorities on how to make signals better.

We expect the impacts of the scheme to be:

- more responsive traffic strategies

- better understanding of options for a UK authority to use C-ITS for signals

- awareness of York's citizens to connect their vehicle data to improve their journeys

The problems to be solved

The A59 corridor forms the main arterial route into the city centre from the north west and links York with the A1 and Harrogate. It also forms the main route into the city for many commuter settlements located to the north west of the city and so is important in ensuring residents have good access to services and employment. The route also carries a park and ride service, numerous local and long-distance bus routes. The A59 also sees high levels of cycle and pedestrian activity and is provided with designated facilities for these traveller groups along its length. The need to accommodate high levels of usage by varied modes of transport within constrained physical limitations are why efficient and effective urban traffic control are essential, both for travellers on the A59 corridor and for the city more widely.

The map in figure 1 shows:

- The park and ride site
- The nature of the route as a main arterial route into the City

- The outer and inner ring roads
- Controlled bus priority at the Sovereign Park and Windmill rise bus gate
- Large residential sites feeding the corridor
- Confluence of two corridors feeding the station area
- The extents of the "York Central" former railway land development area

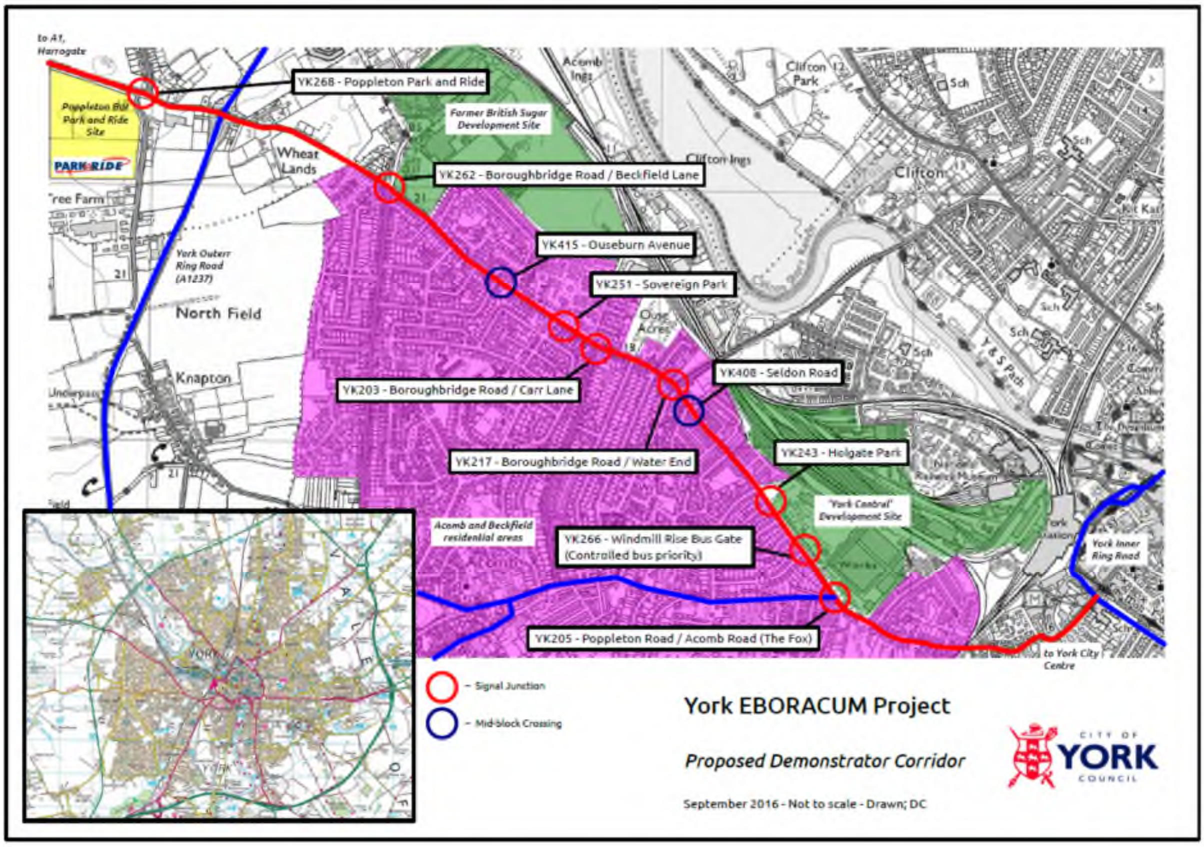

Figure 1: The A59 Corridor

The project architecture

The key elements are shown below:

- Connected vehicle data via ITS-G5 (future tests)
- App data from OBD2
- INRIX FVD data
- Harvested wifi data
- A process for matching wifi harvested data to produce current and predicted journey time for various vehicle types
- A cloud database (hosted on Amazon Web Services) to store the data which can be expanded for future data
- Links to the COYC UTC systems and other tools such as the virtual emissions monitor from Dynniq

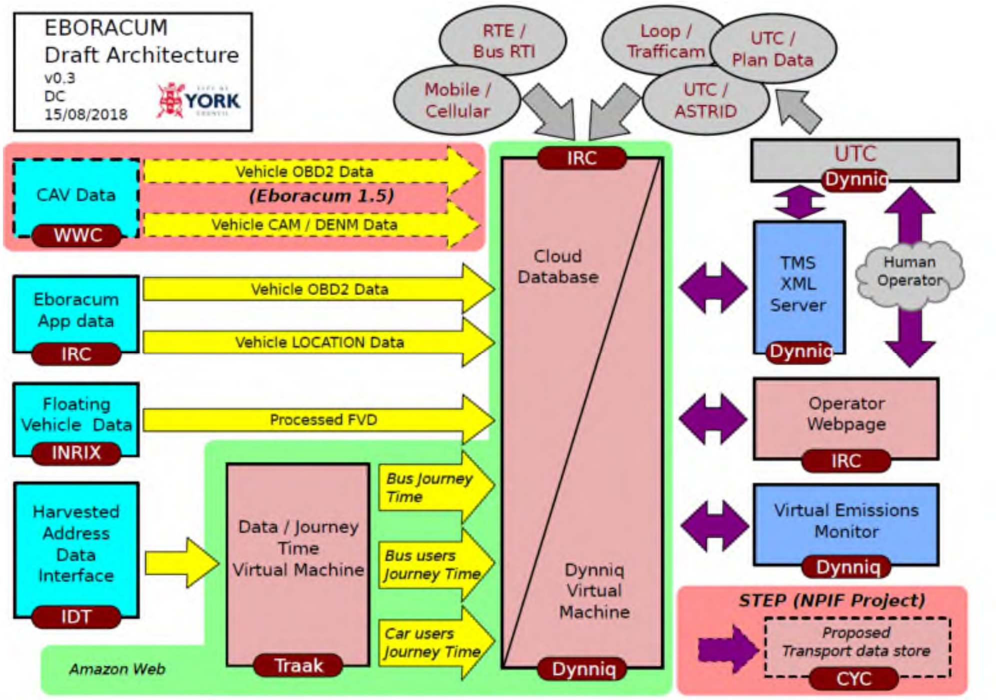

Figure 2: Overall project architecture

Journey time collection

The key to the project is having two different types of journey time. Vehicle based, derived from INRIX's fleet of GPS equipped vehicles and provided as a service of processed vehicles times, and infrastructure based using Wifi.

The INRIX data was chosen as it offers a development path to future traffic signalling strategies using individual vehicle data. Work in Purdue University in the US[1] has already shown the ability to elaborate GPS data from vehicles approaching signals, check their passing on green and hence adjust signal timings to improve efficiency, using historic data in the first instance and possibly in near real time in the future. INRIX are now exploring this with Transport for West Midlands in another project. The INRIX data also provides and an independent benefits assessment data set if the infrastructure-based data is used as a control input, and vice versa.

The core of the journey time infrastructure is IDT's iMesh devices installed along the A59 corridor. These harvest the MAC addresses of passing wifi-enabled smart devices (phones in cars, electric buses, cyclists, vehicles with wifi hotspots etc). We chose wifi instead of Bluetooth as:

a) It is likely to grow in sample size with more and more vehicles having wifi devices on board
b) We can do more balanced journey time assessments (eg by capturing a cluster of wifi units onboard an electric bus itself with wifi)
c) To inform about the properties of a wifi based communications system

The harvested MAC addresses are then anonymised before being sent using the UTMC Community's ANPR data exchange format to Traak Systems for matching and processing.

Journey time processing

1 Darcy M Bullock – paper 1 6=001 1 6-01 1 2 Opportunities for Detector-Free Signal Offset Optimization with Limited Connected Vehicle Market Penetration: A Proof-of-Concept Study

The IDT data comes into the Traak Journey Time System as a stream of individual records. These each contain a hashed MAC address, a timestamp, and an identifier, where these identifiers can be used to reference the locations of the IDT devices picking up the respective Wi-Fi signals.

Using a bespoke algorithm, which can take into consideration sample noise from multiple concurrent readings, these distinct readings are then transformed from individual hits with just a time and a location, to a journey between IDT devices with start and end locations, together with time taken.

The next stage in the pipeline is two-fold. First, due to the nature of the records, outlier removal must be performed on the data to ensure quality. That is, since a journey could involve several intervening stops, not able to be accounted for in the data, clear outliers must be removed: this is implemented using Tukey Fences[2]. Secondly, to further ameliorate noise, journey times between any two IDT devices are aggregated into five-minute intervals using the arithmetic mean.

Having obtained aggregated journey times, it is then possible to fit models to this time-series data in order to predict the traffic conditions accurately for at least the next 30 minutes. After much experimentation, this was found to be achieved best by using calibrated exponential smoothing models which incorporate the Holt-Winters method[3 4].

Finally, to make analysis and visualisation easily accessible, a dashboard was created for this project using the latest web technologies, where aggregated metrics over a given geographic area can be viewed to see if any problems are occurring in real-time. and then more detailed journey time data can be drilled into at any arbitrary time-scale. This allows the user to see at a glance when there is a problem, where it is, and, together with third-party data sources, get a feel of what the root cause is so that the situation may be resolved and or avoided in future.

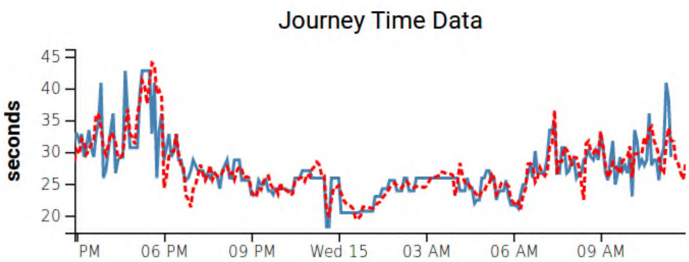

Figure 3: An example of aggregated journey time data for a section of the A59 plotted in blue, versus our fitted model with 30-minute predicted journey time plotted in red

Signals Aspects

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2 *Tukey, John W (1977). Exploratory Data Analysis. Addison-Wesley. ISBN 0-201-07616-0*

3 C. C. Holt (1957) Forecasting seasonals and trends by exponentially weighted moving averages, *ONR Research Memorandum, Carnegie Institute of Technology* **52**

4 P. R. Winters (1960). Forecasting sales by exponentially weighted moving averages. *Management Science*, **6**, 324–342

The aim of the signals work in Eboracum is to determine how individual vehicle data, in its various forms, can be used to optimise signals without major software or hardware development and with immediate positive impact on network performance. The first step in this process is simply to utilise the additional insight gained from the data to reconfigure existing fixed time signal plans, this is currently being conducted by COYC. Beyond this, the challenge is to utilise the new data in real-time to optimise signals in an automated, adaptive fashion. The ultimate aim is to achieve better performance than SCOOT and MOVA with no local detection at all. But recognising that this is a lofty goal, and that a hybrid of local detection and external data may be more powerful in the short term, we are working towards it in small steps.

Dynniq are prototyping several 'over the top' algorithms which can operate alongside an existing UTC system to enact optimisation without reliance on local on-road detection. Dynniq's TMS SCOOT UTC provides API access to the majority of functionality so it is relatively straightforward for an external application to access data from within the system or to request signal plan or stage changes with no changes to the software of the UTC system itself or any of the roadside hardware.

Planned 'day one' modes of operation consist of switching between existing plans or optimisers – something which we call 'hyperoptimisation'.

1. Switching from SCOOT to fixed time, using triggers based on vehicle data
2. Switch between a large library of incrementally different fixed time plans based on vehicle data

The project architecture also supports stage-based control, whereby the external algorithm drives stages in the same way that SCOOT does currently. These options are outside the scope of the current Eboracum project but are considered feasible with only modest vehicle data penetration:

- Adjusting splits, cycle times and offsets in an incremental fashion based on recent historical transit times through the network
- Building of cyclic flow profiles over multiple cycles using partial samples as per the Perdue approach

And, of course, should vehicle data reach high penetration we enter the realm of entirely new, far more sophisticated optimisers where virtually every vehicle's path is tracked and projected in detail through the network, with the optimiser dynamically assembling phases into stages on the fly, issuing instructions to vehicles to form into platoons to hit the green light and constantly balancing travel times, emissions, noise, user experience, modal balance etc. to match the priorities of the transport authority… but we said small steps.

Current status and lessons learned so far

The architecture has now been deployed on the A59 corridor and "before" data is being collected. A key lesson was that connecting new roadside devices to an existing local authority system required detailed understanding of configurations and setup of devices, and also that mobile phone masts can interfere with wifi devices. This may need further exploration.

The INRIX data has proved useful, not just for Eboracum, but as a tool for more general traffic control. Allied with MAC address data this gives two different but complementary ways to measure journey time with no in-road equipment. Another lesson is that by careful design in-vehicle devices connected to the ODB2 port such as tablets and mobile phones can give high granularity location data to a roadside device. This may be useful in the future for signal setting to avoid reliance on just new vehicles being equipped and also open up new policy tools

GDPR was raised by COYC and a detailed Privacy Impact Assessment carried out of the end-to-end system. We learnt that even though the IDT equipment, ANPR MIB and MAC address harvesting are in common use and the data is anonymised, further steps need to be taken to consider wider use of the data within the GDPR regulations.

Another lesson is that all ITS-G5 devices are not the same. The compatibility between roadside and on-board units needs careful checking.

A final lesson, and perhaps the most important, is that equipping just one corridor for use of connected vehicle data has not been as straightforward as foreseen. Extrapolating this for support for connected vehicles and then autonomous ones for a typical UK small city suggests it will be a challenge of skills and resources, and of timing.

This is a message for those expecting Local Authorities to install significant infrastructure quickly to support future innovations – the roads need to be connected also.

Next Steps

Now that the data is being collected, the next steps are:

- Refresh Isolated traffic signals
- Running SCOOT as a baseline for comparison of signal strategies
- Testing the efficiency of new signal plans and strategies against these, using INRIX journey times and wifi MAC address harvesting as measures of performance
- Looking at the use of ITS-G5 beacons and in vehicle units supplied by Middlesex University, to compare and contrast three different ways of obtaining vehicle location data
- Exploring end to end collection of data from the vehicle itself through the ODB2 port using an app developed by IRC. This could be used for example to detect vehicle powerplant, emissions faults or more granular vehicle position
- Expansion of the A59 corridor approach to all of the City of York's main arterials, within the COYC STEP programme, which is funded by the National Productivity Innovation Fund.

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