Enabling MaaS Through a Distributed IoT Data Fabric, Fog Computing and Network Protocols.

Background

Transport networks in cities and regional centres are under increasing pressure from escalating customer demand. Fuelled by population growth, increasing urbanisation and expanding customer expectations, governments and private sector transport operators are facing new challenges.

In short, we have more and more people needing to travel across increasingly congested cities and towns. At the same time, our expectations of good customer experience are heightened as business and government have embraced digital channels and innovated their service delivery.

Whether we're checking our bank statement, ordering pizza delivery or booking a ride to the airport, we all strive for a seamless, convenient customer experience.

Introduction

Transport networks and services have been enjoying renewed levels of investment in recent years, with more needed going forward. This investment has been required to meet the demands of growing populations and increasing urbanisation, and support associated economic activity. In many instances it has also been needed to address prior decades of underinvestment resulting in both a maintenance backlog and an urgent need for more capacity.

However despite renewed investment, travel times in most cities continue to increase as our roads become more congested. Our public transport services - buses, trains, trams and ferries are more frequently crowded. And many transport modes - be it road or rail - are displaying signs of stress as journey times become more unpredictable in the face of unplanned incidents and ever-present maintenance requirements.

A new era of innovation

Our traditional response to these challenges has been to increase supply. Build new roads, upgrade rail lines, and run more services. And there's no doubt that improved capacity will be needed going forward.

However, a new suite of approaches for solving our transport needs is emerging. The first wave of this change has been the innovation in digital channels and online services. This began with the advent of online journey planners and real-time customer information – enabling people to discover, plan and connect with transport services quickly and easily. A second wave of innovation is now well underway, spearheaded by the introduction of new transport options such as ride-sharing, bike-share and car-share. Largely defined by collaborative consumption business models, this tranche of innovation is built on the foundations of digital transformation, social networking and frictionless data exchange.

A third wave of innovation is now building steam. This will focus on providing end-to-end mobility experiences. This wave of change - labelled as Mobility-as-a-Service (MaaS) - is focused on:

- Providing customers with personalised journey options, based on up-to-minute service and disruption information.
- Integrating journey planning, service booking and payments into a seamless experience.
- Bundling transport services into convenient and cost-effective 'mobility plans' - similar to a mobile phone plan for your travel needs.
- Filling gaps in the transport network by offering innovative new transport services for first- and last-mile connectivity.

The missing piece of the puzzle

Amongst these transformations and the advent of MaaS networks there is a risk that governments and business maintain their traditional focus on supply without innovating on the demand side of the equation.

Many of the new mobility operators have developed a detailed understanding of customer demand. Mobile booking apps, location tracking and data analytics underpin this capability – which enables operators to plan capacity in the medium-term, and to rapidly respond to peaks in customer demand in the short-term.

The result is an optimised business model, and benefits for customers and operators alike.

However when we zoom out and look at things at a city or town level, in this model we still lack the ability to manage and respond to demand across multiple, disparate operators. If we're going to solve our cities' mobility challenges at scale, then we need the ability to sense and respond to demand rapidly and seamlessly.

Challenge

- Transport networks in cities and regional centres are under increasing pressure from escalating customer demand
- Travel times in most cities continue to increase as roads become more congested
- Public transport services buses, trains, trams and ferries - are more frequently crowded Journey times are increasingly unreliable as transport networks are under pressure from planned maintenance and unplanned incidents



Emerging Mobility-as-a-Service marketplaces promise greater

- flexibility with a seamless booking and payment experience
- New point-to-point and on demand transport operators are beginning to solve first- and last-mile needs
- An open data exchange underpinned by edge computing power, dynamic data exchange and flexible policy configuration can deliver a step change in customer experience, and transport network efficiency



 Connecting existing sources of transport demand data – along with new customer insights – in an open MaaS marketplace can dramatically reduce journey times, and unlock transport network capacity

Connecting the edge and fog

Edge and Fog computing offers the potential to understand latent transport demand in real-time, and to rapidly assemble insights which can allow MaaS networks to quickly deploy services and get people moving.

Adding edge computing capabilities to MaaS networks and therefore building an IoT Data Fabric has the potential to unlock a new approach to optimising transport networks. The objective here is to deliver a demand-responsive transport ecosystem, where the MaaS network enables multiple mobility operators to detect and understand customer demand in real-time.

Coupled with the advent of new first- and last-mile solutions, on-demand transport services and 'high bandwidth' road and rail corridors, a demandresponsive MaaS network has real potential to improve mobility at a city scale.

Research overview

The University of New South Wales (UNSW) and Cisco collaborated on a research investigation to explore the utility of real-time transport demand data in the context of emerging Mobility-as-a-Service (MaaS) networks.

The research team captured and measured transport customer experience in terms of waiting time at transit hubs (such as bus stops) and overall journey time (incorporating waiting time and trip times from origin to destination).

Using a variety of data sources and capture mechanisms, Cisco's Kinetic IoT Data Fabric platform was used to rapidly assemble and process real-time transport demand metrics. Collaborative research at UNSW's Research Centre for Integrated Transport Innovation (rCITI) and School of Electrical Engineering and Telecommunications (EET) has calculated customer experience metrics via the Cisco Kinetic platform and modelled various MaaS scenarios to understand the impact of dynamic demand response on journey times and overall customer experience.

Unlocking demand data

The research investigation involved ingesting four sources of data into the Cisco Kinetic data exchange platform, listed as follows:

- Aggregated and anonymised Wi-Fi hotspot connection counts from UNSW Campus IT, containing the timestamped number of authenticated connections to two access points located near high demand bus stops. We use this data to estimate the number of travellers waiting at bus stops, as an approximation of transport demand.
- Opal card tap on and tap off aggregated (and anonymous) data from TfNSW. This data was timestamped and enabled the Cisco Kinetic platform to estimate transport supply metrics, along with public transport trip time.
- Location history data sourced via the Datrum data sharing platform. Datrum enables individuals to reap rewards by securely and privately sharing their social media information. For this project, Datrum provided aggregated and anonymised location history data - enabling the Cisco Kinetic MaaS trial to calculate potential ride-sharing and ride-pooling opportunities.
- 4. Travel time data from Google's publicly Distance Matrix API to estimate private vehicle journey times for selected origin-destination pairs.



Figure 1: IoT Reference Model

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Dynamics of demand and supply in transport networks

The team quantified the first component of customer experience, namely the average waiting time at bus stops near the UNSW campus using WiFi connection data. This was combined with the calculated transport service rate using Opal card data.

Figure 2: Demonstration Topology



Using the Kinetic platform real-time transport demand and supply is computed for each bus stop (shown respectively as N and μ in Figure 3).

Figure 3: Kinetic data exchange platform



A queuing model was configured in the Kinetic platform, enabling waiting times and demand and supply metrics to be dynamically calculated in real-time.

A second component of customer experience – average trip time in traffic – was also calculated on the Cisco Kinetic platform using a combination of Opal card trip data and real-time Google traffic metrics.

The Cisco Kinetic platform then applied the metrics as inputs to various MaaS policy configurations to simulate dynamic assignment of additional transport capacity to improve travellers' experience and overall system performance.



Networks are networks

Our research investigation explored a number of parallels between communication network engineering and the operation of transport networks. These concepts were used to refine the simulation and modelling of the MaaS operations on the Kinetic platform.

Communication network concepts	Equivalent MaaS policies
Dynamic resource allocation: It is a technique in data communication networks for providing additional capacity (on a link or cloud computing resources) as necessary to accommodate bursts in data traffic, a videoconference, or other special requirements.	On-demand mobility: Optimising the allocation of available mobility capacity or supply to when and where there is demand for travel, minimising the mismatch between demand and supply for travel.
Load balancing: It is the ability to balance network traffic (compute load) across multiple links (servers) without using complex routing protocols. Load balancing takes advantage of the network scalability and agility to meet rerouted workload demands and to improve overall availability.	Peak spreading: Peak spreading describes the broadening of demand for travel (or traffic) over time and space. For example, if there is a long queue of passengers at a certain bus stop, we may encourage a fraction of those passengers to walk to the next nearest bus stop and/or take another route to reduce the crowding and waiting time for all passengers.
Internet Traffic Engineering: It involves adapting the routing of traffic to the network conditions, with the joint goals of good user performance and efficient use of network resources.	Traffic Engineering: It involves use of various modes of transport (public and private) to minimize trip time and maximise utilisation of transport resources by encourage adaptive driving or route shifting.
Congestion Control: The TCP congestion-avoidance algorithm is the primary basis for congestion control in the Internet. It is implemented and maintained by the traffic sender and is used as a means of stopping a link (between the sender and the receiver) from becoming overloaded with excessive traffic.	Travellers Information: This informs travellers in case of congestion at a certain bus stops or location in the network to hold back, change their travel plan, update their departure time or try a new pick up point.

The impact of demand responsiveness and dynamic supply

Following the quantification of customer experience, the team simulated different MaaS policies to dynamically allocate on-demand transport services, reducing the waiting time of travellers.

For example, in one simulation if the computed average waiting time of travellers at the bus stop exceeded five minutes, a MaaS policy was applied to deploy an additional 10 mobility units (i.e. seats available on deployed demand vehicles).

In another simulation an additional 30 mobility units (additional seating capacity on deployed on demand vehicles) was allocated when average waiting time exceeded 10 minutes.

These simulations emulated the effects of dynamically increasing the supply of transport capacity based on real-time detection of customer demand.

Figure 4: Real-time wait-time of travellers at bus stop for different MaaS policies.

In a MaaS environment this would mean additional on demand pooled or point-to-point vehicles would be automatically deployed to areas of peak customer demand – thereby improving overall customer experience through increased mobility.

Ride-pooling to increase system efficiency

Customers who are willing to share personal, yet anonymised, location history data and are identified as ride-pooling candidates through having similar destinations can benefit from a shared (pooled) mobility option - and improve the overall efficiency of the transport network.

Individuals can enjoy a shorter trip time due using a customised route in a shared, on demand vehicle with less congestion compared to a static route used by traditional public transport services.

In our simulation, we assumed that a fraction of travellers (approximately 10%) waiting at the bus stop are willing to share a ride with other travellers who share similar destinations.



Baseline (without MaaS)
MaaS with dynamic supply
MaaS with dynamic demand

MaaS with both dynamic supply & demand

Wait time at bus stop: Given the assumed scenario, we show that the dynamic supply policy (on-demand mobility services) can yield about 40% reduction of waiting time at bus stops (shown by orange lines in Figure 4) compared to the baseline scenario (shown by blue lines in Figure 4). While incorporating the concept of load balancing (dynamic allocation of customers to ride-pooling) alleviates demand loads at the bus stop, hence yields a reduction in average waiting time by 62% (shown by green line in Figure 4). Finally, the combination of both policies will result in the lowest average waiting time, shown by red lines in Figure 4.





Figure 5b: Average wait-time of travellers at bus stop.



Travellers' arrival and departure patterns along with the average wait-time is shown in Figure 5.



Figure 6: Real-time journey time (minutes) for different MaaS policies.



Total journey time: The MaaS policies can also enhance the trip time and consequently the total journey time as another measure of travellers' experience. We show that the average journey time can be reduced by 9% using dynamic supply policy (shown by orange lines in Figure 6). Dynamic demand can result a reduction of 18% in the average journey time, shown by green lines in Figure 6.

Figure 7a: Static route (of regular public transport) versus dynamic route (of private transport) for a given source and destination.



Figure 7b: The average journey time.



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Conclusion

Measuring customer experience in complex, decentralised transport ecosystems is challenging. In this research project, we have explored, for the first time, the application of a dynamic Edge and Fog computing data exchange platform. Using the Cisco Kinetic IoT Data Fabric platform we have collated disparate real-time and reference data sources, and used distributed computing power to measure customer experience and provide demand-responsive and dynamic supply in the context of a MaaS environment.

We have shown that the developed framework can improve the performance and efficiency of future mobility systems – delivering benefits for individual travellers and the broader transport network.

The outcomes of the project shed light on a promising direction for future exploration and investment that could enable transport agencies and MaaS operators (large and small) to exchange information through a secure platform.

Emerging MaaS environments (and existing public and private transport operations) typically work in silos with limited real-time data exchange among operators, customers and government agencies. We believe mobility services, individual customers and urban transport networks can benefit from dynamic open data exchange for transport demand – which would underpinning intelligent deployment of on demand MaaS capacity.

The solution demonstrated and tested in this research project can be taken forward by government agencies and transport operators to accelerate the development of a mature, efficient MaaS framework.

In collaboration with





