A guide to the TULIP Platform Minimum Viable Product (MVP)

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Introduction

TULIP is the University of Technology Sydney's leading smart city project delivery program. It is a joint initiative from the Institute for Sustainable Futures (ISF) and the Faculty of Engineering and IT (FEIT). TULIP is represented at FEIT through the Knowledge Economy Institute (KEI).

TULIP focuses on environmental monitoring for urban liveability and was founded in 2016 by UTS and a consortium of affiliated industry partners. A pilot program in the city of Sydney established a basic approach and vision for TULIP and provided important foundational expertise in the space. TULIP is now being significantly developed in the context of the *Liveable Neighbourhoods in Lake Macquarie and Sydney City* project.

The core capacity of TULIP is an open, modular and flexible data architecture that represents a departure from the standard vendor-controlled proprietary data stack. UTS recognises the importance of developing a collaborative ecosystem of many technology partners, each playing to different strengths. The TULIP platform does exactly this, providing councils with access to and flexibility with all levels of the data architecture, from device management, up through ingestion, to data storage, analytics, visualisation and actuation. Importantly, TULIP has the capacity to manage and ingest data from multiple device types across multiple networks, standardise data formats and labelling and collate a broad range of outputs in one place. The platform is designed to be as open and accessible as possible, at all levels, meaning that new capacities can be continually added or indeed removed.

The longer-term vision for TULIP is to build capacity and knowledge in the smart city space through real-world experimentation and active collaboration with government and industry in order to establish UTS as the leading university on smart cities in Australia.

This document

This document refers to the 'Minimum Viable Product' (MVP) of the TULIP platform, developed in the context of the *Liveable Neighbourhoods in Lake Macquarie and Sydney City* project, which is being delivered by the University of Technology Sydney (UTS) in partnership with Lake Macquarie City Council (LMCC) and the City of Sydney (CoS)

The Australian Government's $50 million Smart Cities and Suburbs Program (SCSP) is supporting the delivery of innovative smart city projects that improve the liveability, productivity and sustainability of cities and towns across Australia. The *Liveable Neighbourhoods* project is one of 49 round 1 SCSP grant recipients and has a total value of $866,000. The project commenced on the 17th of November 2017 and runs to the 30th of June 2019.

This document is a report on the early development of the TULIP platform and a practical user guide for accessing and navigating the first user dashboard for data visualisation.

TULIP Data architecture and functionality

A) Overview of TULIP platform architecture

Technology for Urban Livability – TULIP – is a smart city project delivery and research program lead by the University of Technology Sydney (UTS).

TULIPS' mission is to harness the Internet of Things (IOT) to build better, more livable cities, where people are placed at the heart of solutions. Technologies must be designed, integrated and delivered around the needs of communities.

TULIP is a blueprint for local governments and communities to design, build and deliver smart city infrastructure on their own terms. Our approach to data architecture is collaborative, modular, open, flexible, network-agnostic and capable of aggregating **any type of data from across a city** in one place - or pushing it somewhere else if preferred. **It's the antidote to proprietary systems and vendor lock-in** that is absolutely critical for local government that are serious about their smart city potential.
The technology solution for TULIP is delivered by four technology suppliers. These suppliers have come together to integrate best-of-breed components into an architecture that realises the TULIP blueprint.

For TULIP, each supplier has focused on a different layer within the IOT stack as defined in the IOT Alliance Australia WS7 Platform Selection Guide v1.0. This approach realises the TULIP goal of a modular, open, flexible, network-agnostic solution.

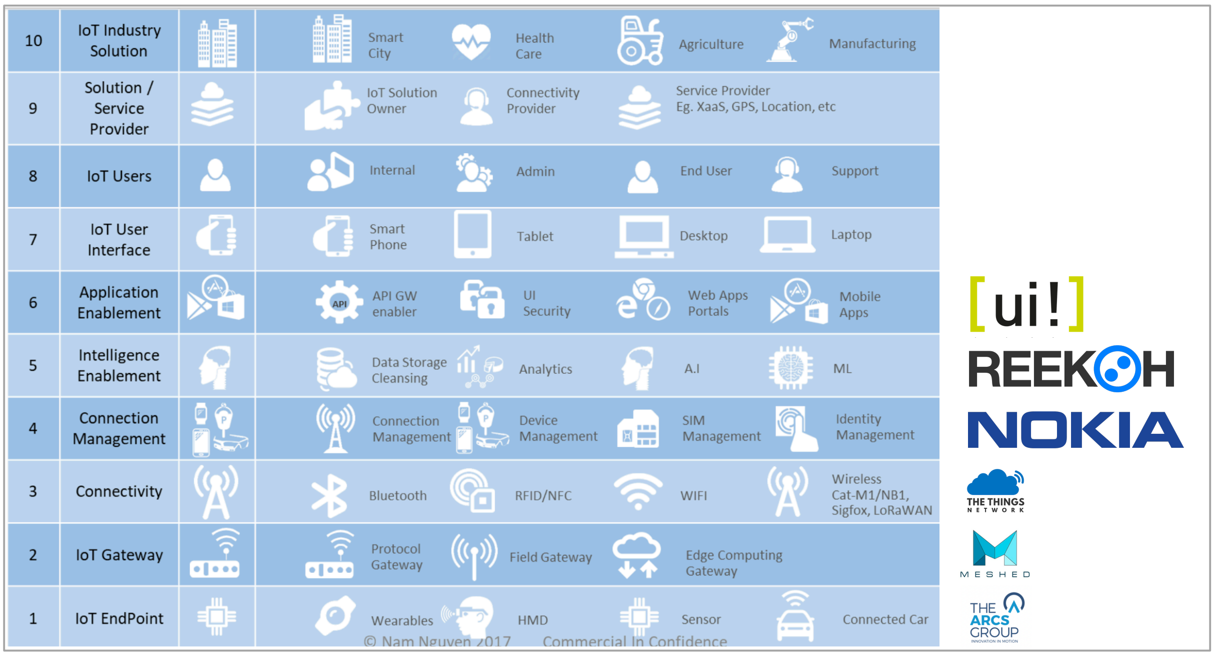
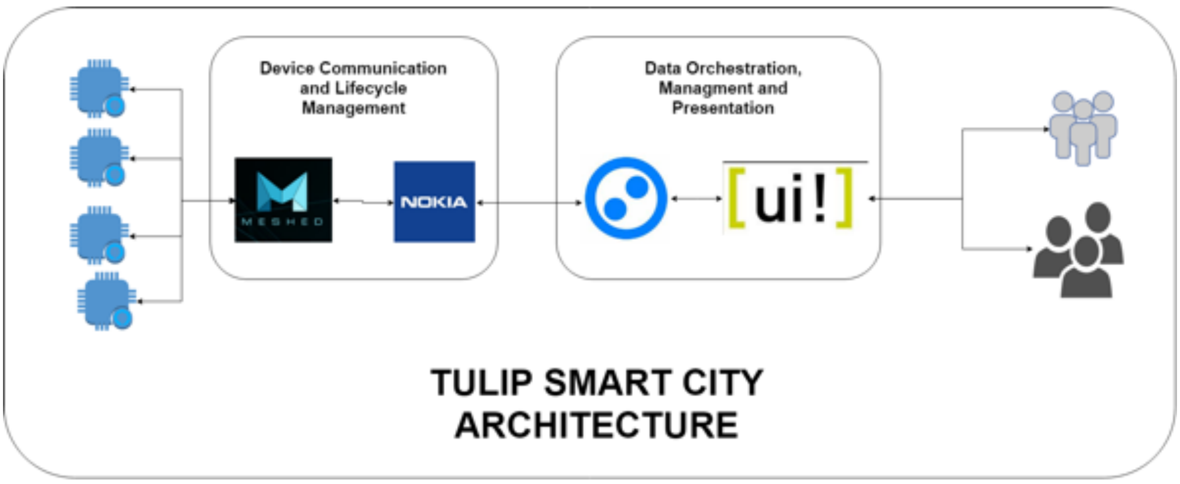


Figure 1 IoT architecture map (from: IoTAA Platform Selection Guide v1.0 May 2018)

The functions that each supplier has concentrated on

Meshed	Nokia
Provides the LoRaWAN Low Power Wide Area Network that connects the devices.	Provides Device Management to enable scale and manage device lifecycles. Is the device meta-data DBOR. Normalises networks and devices to provide a network-agnostic substrate.
Reekoh	**UI**
Provides data pipeline and takes complexity out of integration. Flexibility to choose end destination for the data. Payload Decoding and Data enrichment from Federal / State Environmental Networks.	Provides data storage, analytics and visualization, designed specifically to meet the needs of Smart Cities. Frees single data domains from their isolation, connecting and integrating them to enable new services and business models.

The communications flow between the components in the TULIP architecture is depicted in the below diagram. State-of-the art integration interfaces and software techniques have been used to integrate the component systems into a complete IOT solution.



Detailed view of the TULIP data architecture

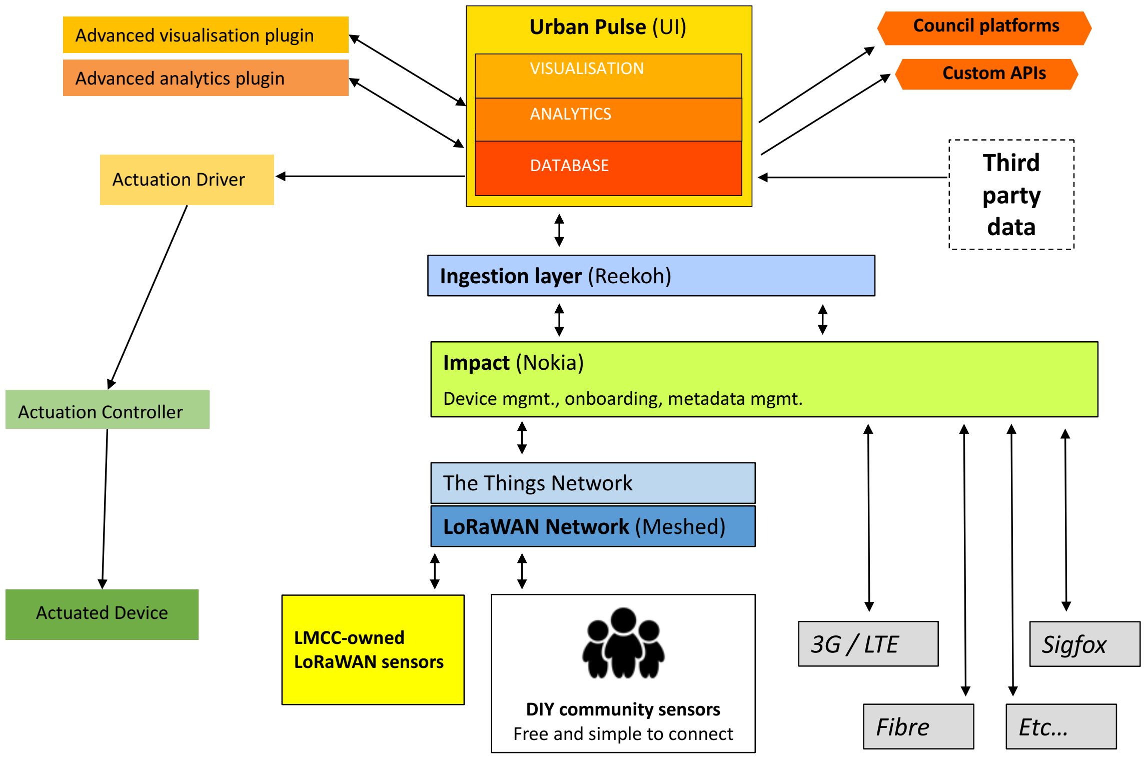


Figure 2 TULIP Data Architecture

Implementation

Why TULIP?

Given the interest in and breath of use cases encompassed by the Internet Of Things it is not surprising that there is a plethora of platforms and solutions on offer from a range of vendors and integrators. This array of offerings can easily become bewildering for potential customers, especially relatively smaller entities like local councils.

The TULIP approach to implementation has been to break the solution architecture out into key layers and modules. This decomposition eliminates dependencies on individual suppliers and monolithic solutions, ensuring customers are not locked in to rigid offerings and are able to leverage the best components from a range of suppliers.

TULIP has pursued four main areas of modularisation:

1. A connectivity module that is fit-for-purpose for Smart Cities and is open to easily integrate higher layer modules
2. An abstraction module to allow thousands of devices of all different types to be managed in a consistent manner, so that customers don't become consumed by having to manually manage their device assets
3. A data ingestion, manipulation and enrichment module that draws together the available data into a usable set from which insights can be drawn
4. A data interpretation and visualization module that makes sense of the data and presents this to the end users.

Details of the modules and their design are provided in the following subsections.

Connectivity Layer

LoRaWAN is one of a number of new low-power wide-area networking (LPWAN) radio access technologies that are underpinning the rise of the Internet Of Things. LoRaWAN differs to other LPWAN technologies in its wide de-facto standardization and openness, resulting in a low cost of deployment and the low cost of devices. As such it has been enthusiastically embraced by councils and communities to deliver their IOT projects without relying on traditional telecommunications suppliers.
The Things Network (TTN) is an initiative to deliver a global LoRaWAN network through contributions from individuals and enterprises in an open and collaborative manner. The Things Network and LoRaWAN are ideally suited to the TULIP project. Within Australia, Meshed is an IOT Integrator that deploys The Things Network for key market segments like Smart Cities. Meshed have driven the deployment of LoRaWAN gateways and the connection of devices for the TULIP project.

Connection Management Layer

A range of commentators on the Internet of Things have produced predictions for the likely count of devices that will be connected in the forthcoming years. These predictions count in the millions and billions.

One of the lesser discussed aspects of the Internet of Things is how IOT-enabled customers are able to cost-effectively manage the large inventory of devices that they will employ in their future businesses. The problem is analogous to the wide-scale introduction of PCs and laptops into businesses nearly two decades ago now. At the time, whilst increasing productivity and being more competitive in the marketplace, many businesses also experienced a significant increase in costs in managing this new, large inventory of devices, especially as it involved ongoing software upgrades. This resulted in the development of tools and modules that eased the PC/laptop management burden. The same style of solutions is required for the Internet of Things.

Nokia is a technology vendor that builds products for the worldwide communications market. Within the IOT domain Nokia has one of the most mature IOT Device Management platforms on the market. The IMPACT product is designed to manage millions of devices in a cost-effective manner. This product addresses the needs of TULIP for modular device management. The platform also abstracts devices so that higher-layer modules need not care about the type of network to which the device is connected (e.g. LoRaWAN, NB-IOT, 3G or other).

Intelligence Enablement & Application Enablement Layers

At the heart of the Internet of Things revolution is data. The low-cost capture of data from sensors and sources is simply the foundation of IOT, not the end. The end is the processing and use of this data to drive new and different outcomes. And coupled with this, the sharing of data across disparate entities.
The TULIP project has spent considerable time implementing data ingestion, matching, storage, analytics and visualization to produce insightful and actionable outcomes for Smart Cities. It is the techniques and technologies employed at the data layers within the IOT stack that make the "smart" in Smart Cities truly come alive.

Two key suppliers in the IOT intelligence enablement and application enablement layers are Reekoh and Urban Institute. Their respective systems have been integrated to provide a complete, modular data processing solution for TULIP. This all comes together visually via the Cockpit that the user sees.

System Integration

The above subsections describe the components that have been integrated as a single platform for TULIP using some of the latest IT interfacing protocols and techniques. This subsection details these integrations.

[A later version of this report will provide further details on the integration of the modules]

B) Overview of Sensor onboarding and metadata management plan

i) Onboarding of devices

Device onboarding is the process to add a new device to the TULIP platform. It is the steps that a device owner undertakes to connect to the networks and systems that comprise the TULIP platform. This process is analogous to connecting a new mobile phone to a mobile telecommunication network.

The onboarding process involves populating meta-data and configuration parameters into multiple provisioning points in the TULIP architecture and other related databases. For example, device identifiers need to be populated to multiple levels within the architecture (Urban Pulse, Reekoh, Meshed, Nokia), plus device-specific meta-data is loaded into the Device Manager (Nokia).

The efficiency of the onboarding process becomes very important when:

1. Large numbers of devices need to be deployed, and;
2. to provide end users with a good "walk out working" customer experience (i.e. the device appears immediately on the system and there is no offline processing or delay).

For large roll-outs the onboarding process usually also involves capturing installation data, such as photos of the install location and completion status; used to assist with future fault finding, maintenance etc. This data is populated into the relevant databases at the same time as the meta-data and configurations are populated into the core TULIP platform.
A further aspect with the onboarding process is that this is often a two-stage process, especially for large scale deployments. The first stage is an offline, pre-provisioning step where key components are preloaded data. For example, if a council or service provider knows that they are going to deploy 3000 sensors of a given type and is provided with the "address range" of these devices, then the platform is pre-provisioned with these 3000 devices. Within the Device Manager the devices are marked as Not In Use so that they do not appear as active devices to the end user (indeed the GUI should not even display these Not In Use devices).

The second stage occurs when the device is activated during installation. At this point photos are taken of the location, barcodes are recorded, device is turned-on and the status of the device within the Device Manager is changed to In Use. The device then appears to the end user as active and data starts to flow.

Where the device is "bring your own" then obviously stage one above cannot be completed offline beforehand. Hence, "bring your own" device onboarding is a one-stage process with full flow-through provisioning of all components while you wait.

Typically, given the multiple components and steps involved in the onboarding process an orchestration or workflow engine is used to automate the process. The TULIP platform does not include an orchestration engine. Initially a series of scripts have been created to assist with the multiple provisioning points. As the project progresses the plan is to use cloud-based form workflow solutions such as goCanvas (https://www.gocanvas.com/) or iAuditor (https://safetyculture.com/iauditor/) to perform this automation. Solutions such as these are attractive as they enable a structured workflow via PC, mobile and tablet devices, include photos, barcode reading etc, and are able to offload the data into downstream systems (i.e. the TULIP core platform). Tools like these are particularly useful for large rollouts of devices where all relevant information (i.e. photos, barcodes, etc) can be captured by the installer and immediately provisioned into the systems, thus enabling the installer to fully test the onboarded device to ensure that it is working prior to leaving the site. Equally, the same tools/forms enable "bring your own" device owners to also onboard their devices.

ii) Device/Source Meta-data

The TULIP project has identified a range of device meta-data (e.g. location) that needs to be stored within the TULIP platform along with the data provided by the devices themselves (e.g. temperature).

The key initial pieces of meta-data being implemented are:

- Device manufacturer
- Device model
- Description of the sensors on the device (e.g. temperature; humidity)
- Longitude, Latitude
- Device Identifier (e.g. Device EUI)

Second stage meta-data includes:

- Name/address of current location
- Deployment date/time
- Owner
- Battery life
- etc.

Additional future ‘metadata mapping’ has been undertaken and an extensive document of future metadata requirements has been produced. This may be found in the Appendix of this report.

Since the device meta-data is related to specific devices, to ensure architectural integrity the meta-data is stored within the Device Manager. Within the TULIP platform the Nokia IMPACT component uses the custom attributes for devices to store the meta-data.

A guide to the Minimum Viable Product (MVP) TULIP Platform interface in Urban Pulse (July 2018)

About the TULIP platform MVP

The project technical team (notably individuals from UTS, Urban Institute, Reekoh, Nokia and Meshed) have worked from March to July 2018 to produce a 'minimum viable product' for the TULIP platform. As explained in Part 8 of this report, the TULIP platform consists of integrated layers n an architectural stack. Each layer is accessible via its own backend, however the layer that provides the operational and public interface is Urban Pulse, by the Urban Institute.

The TULIP platform MVP involves the following:

- Live Meshed LoRaWAN gateways deployed in Lake Macquarie (at Speers Point and Charlestown)
- Live sensors deployed in Lake Macquarie
- Sensors transmitting data via the Lake Macquarie Meshed LoRaWAN network, with data passing through one of the gateways (in this case, at Speers Point)
- Live data sent to The Things Network
- Data from The Things Network passing to the Nokia Impact platform
- Device metadata stored in Nokia Impact and propagated up the stack
- Data ingested from Impact into Reekoh
- Data interpreted and labelled in Reekoh and pushed on to Urban Pulse
- Data stored in the Urban Pulse Azure Database
- Data analysed by the Urban Pulse analytics module
- Data presented on the Urban Pulse map, with minimal metadata visible

The technical team has achieved the MVP of the TULIP platform and is pleased to present it as part of this milestone report.

What is visible in the TULIP platform MVP?

Please note that the map view opens on Speers Point in Lake Macquarie, where two temperature and humidity sensors are visible. The key thing that we are showcasing is that the full TULIP data stack is operational with live data. The two devices streaming the data are made by a company called Winext and are the first devices of their type that we have activated and deployed. There may be some technical challenges for the first couple of weeks while the TULIP team configures the system to manage them.

If you zoom out on the map and zoom back in on Sydney you will find other temperature and humidity sensors with live data streams. These sensors have been in place since the start of 2018 and data from them is the focus of a report delivered to the City of Sydney (see part 11 of this report), which compared their performance to the performance of an older type of urban heat sensor device. If you wish to see more accurate longitudinal urban heat data, please refer to the sensors visible in Sydney.

The TULIP platform is built to scale. At MVP, the enhanced functionality provided by layers like Impact and Reekoh is not apparent at the level of Urban Pulse. As a result, a lot of the work undertaken to date, to integrate all the platform layers, is not immediately obvious to someone viewing data in Urban Pulse. As the system grows and matures however, we expect the functionality and enhanced system attributes to become increasingly apparent.

The information on the following pages has been prepared by Urban Institute on behalf of UTS. It is intended as a practical guide for users wishing to view live data in the MVP of the TULIP platform.

the urban institute®

How to use [ui!]'s TULIP' UrbanPulse Cockpit

The [ui!] UrbanPulse

The UrbanPulse is a tool that takes data from sensor data streams (such as environmental sensors, smart water meters or EV chargers) as well as from existing systems (such as Enterprise Resource Planning, open public transport data or billing systems). It can then store, analyse and visualize that data so that city officers can better understand what's happening in their city, and provide more cost-effective and innovative services. For TULIP, the UrbanPulse is being used to process environmental data from a number of environmental sensors installed in Lake Macquarie and Sydney.

Cockpit Overview

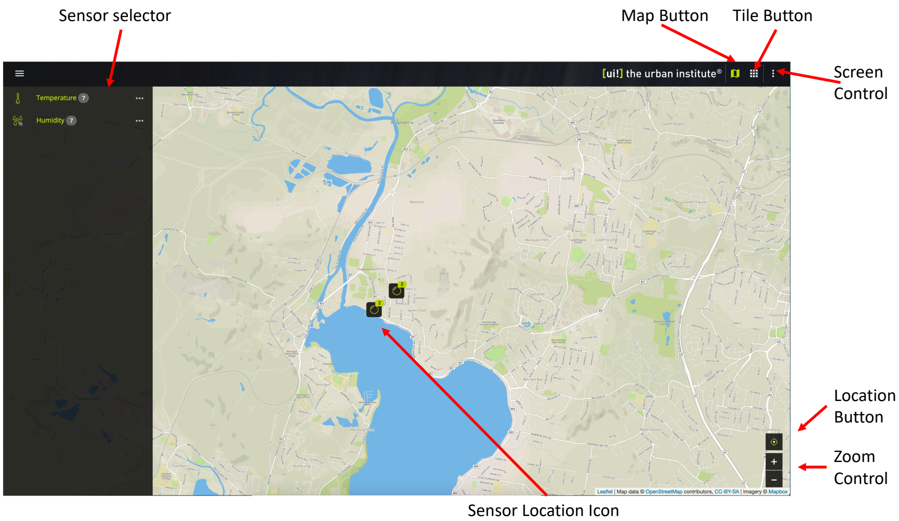
The TULIP Cockpit provides a visual display of information pushed to it from TULIP environmental sensors deployed in Lake Macquarie and Sydney. The Cockpit is best viewed in Google Chrome.

The TULIP Cockpit

The UrbanPulse TULIP Cockpit is located at:
    http://tulip.urbanpulse.de/

To login to the TULIP Cockpit use the following access codes:
    Username: tulip
    Password: hd]aQ7~2nEp#!

Once you are in the TULIP Cockpit you will see this screen:



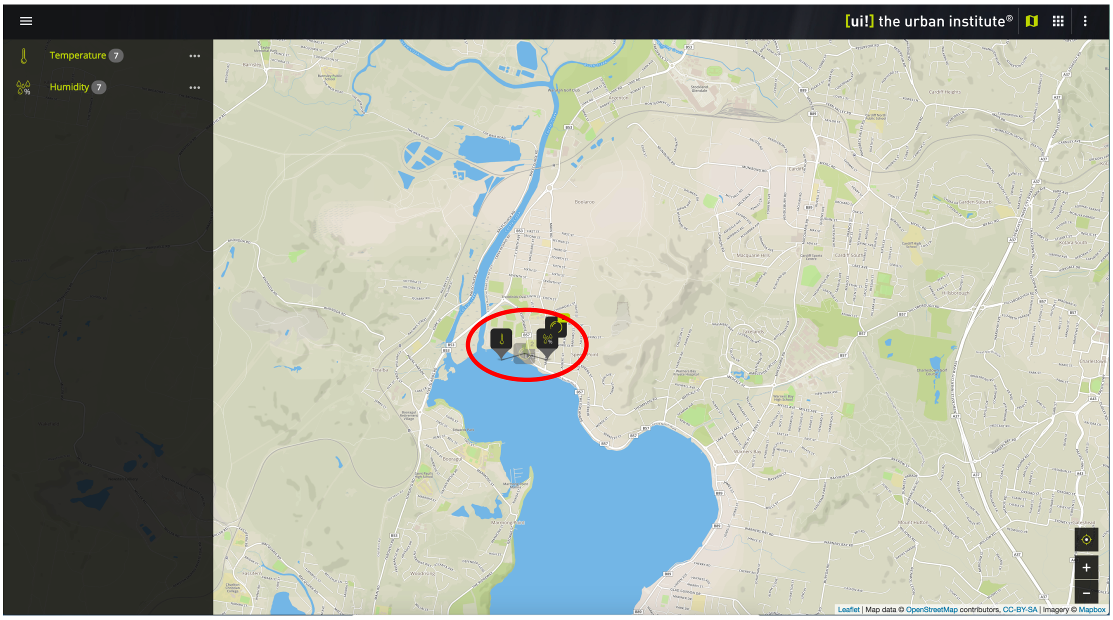
The screen shows the following elements:

1. A map of the Lake Macquarie area, with a number of icons superimposed.
2. Each icon represents the location of a sensor device. Each of these devices holds 2 sensors (temperature and humidity).
3. A sensor selector, which allows you to toggle different sensor types on and off (with only 2 sensor types and only 2 sensors, this may seem a bit silly, but as the mixture of sensor types and locations grows more complex, the ability to see only the information you are interested in can be vital). Clicking the dots next to the sensor types will show a list of all currently registered sensors.

4. A map button, which takes you to this map view (think of it as being like a home button)
5. A tile button, which takes you to the cockpit tile view. Right now we're not using the tile view, but will in the future.
6. A screen control button that allows you to do things like go to full screen mode and log out.
7. A location button, that puts an 'I'm here' pin on the screen.
8. Zoom in/out controls.

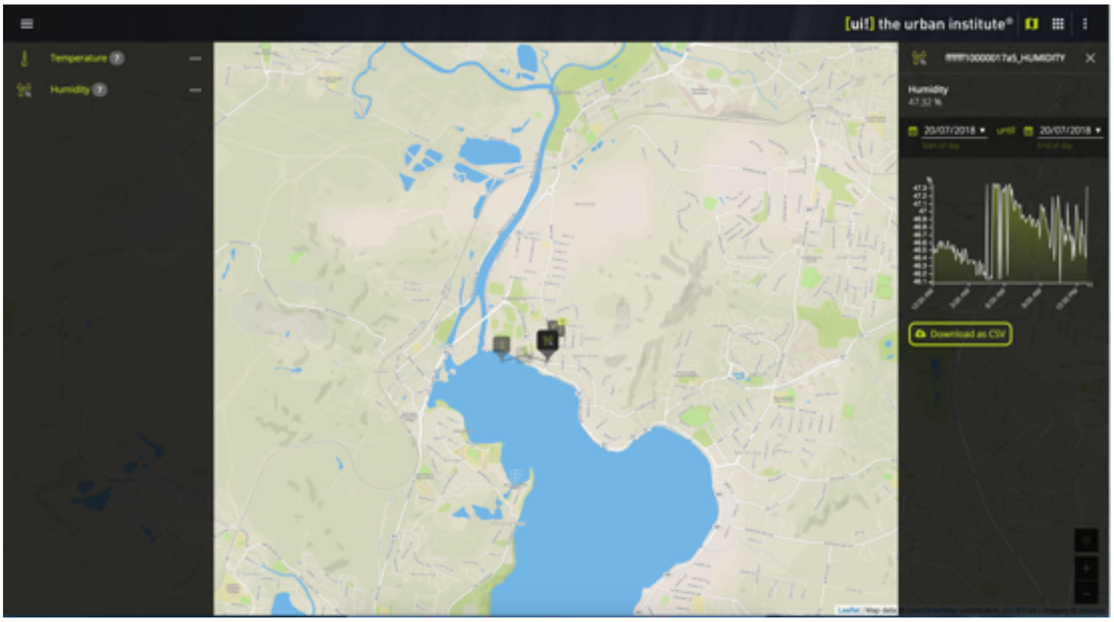
Interacting with the map view

Try pressing on one of the sensor location icons. It will expand to show you more information about the data types available at this location, like this:



You can see the sensor location icon has expanded to show temperature and humidity icons.

Now, click on one of these – for example, the humidity icon. You'll see a detail window pop up on the right of the screen, showing data for a period you select.



In this case, we've shown humidity data for the period of the 20th July 2018, from midnight until the time this screen shot was snapped. You can use the date boxes above the graph to control the data range that's displayed.

You can also download the data as a CSV file by clicking on the 'Download as CSV' button. You may be asked to re-enter your login credentials. The CSV files are saved to the usual Downloads folder for your computer.

Zooming out and looking at data from Sydney

TULIP also has a sensor array deployed in Sydney. This is why the numbers on the temperature and humidity index entries on the left of the screen both say '7' – 2 of these sensors are in Lake Macquarie, and the remaining 5 are in Sydney.

You can find the Sydney sensors by zooming out using the zoom controls, or by clicking on the 'Temperature' or 'Humidity' lines in the sensor selector bar.

The first click will turn the sensor you've selected off. Now the map will only show Temperature icons (if you chose Humidity) or vice versa.

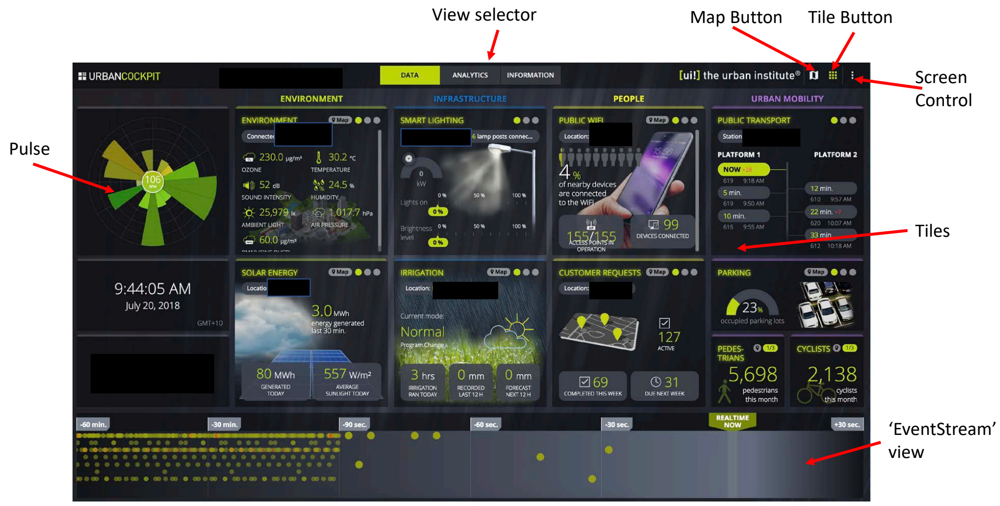
Click again, and the map will show all the sensors – by zooming out, it now encompasses Sydney and Lake Macquarie. Click on the sensor icon over Sydney, and the system will zoom in to Sydney. From here on, it behaves just as with Lake Macquarie, although the sensors have been installed in Sydney for longer, and so there's more data to investigate.

Forthcoming functionality from the Map View

In coming months, the Map view will gain more capabilities, including a richer mix of data types, and abilities to overlay different geometries, etc.

A second Cockpit

The state of development of the TULIP cockpit is such that we've only included simple environmental data thus far. The Urban Pulse, and the Cockpit, can do far more. Let's have a look at another, example cockpit, which we developed for another Australian city. This Cockpit has a much richer data mix, and also makes extensive use of the 'tile view' that the Cockpit supports. (In the screenshot below any identifying images of the city have been blacked out).



In this view of the Cockpit, the visual metaphor is a grid of tiles rather than a map. The elements are:

- The Pulse: A summary view of all the data flowing through the UrbanPulse, and the state of each data source.

- Tiles: This cockpit has 10 tiles, showing:
  - Environmental information from a group of environmental sensors across the city.
  - State of the city's solar farm showing power generated today.
  - Smart lighting information (e.g. brightness of each light, power saved today).
  - Smart irrigation system, which includes using forecast and past rainfall to minimize the amount of time the irrigation system needs to run.
  - Public WiFi information (number of users, number of access points).
  - Customer requests (for maintenance and repair): number of jobs undertaken in the past week, and scheduled for the upcoming week.
  - Public transport data, showing public transport system including service delays.
  - Smart parking information including bay availability.
  - Pedestrian count.
  - Cyclist count.

- View Selector: This allows you to switch between:
  - data view (shown in the image above),
  - analytics view (showing what the data means, e.g. energy saved, pollution status, infringement information), and
  - information view, showing where the data for each tile is sourced from.

- Map Button: allows you to switch to map view, see discussion of TULIP map above.
- Tile Button: Switch to tile view (home button for the tile view).
- Screen Control Button: as for Map view.
- Bubble View: this shows the stream of data coming into the UrbanPulse – it is a visual way of viewing each data event, what tile it relates to, and the details of each data point (seen by hovering the mouse over the bubble).

For an in-depth exploration of a public Cockpit, we recommend you visit https://asca-summit.urbanpulse.de (no credentials required).