Horizon Scanning Series

The Internet of Things

Emerging space-based infrastructure for the Internet of Things

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Background and Context

This short submission is provided as input to the Satellite and Space Technology Work Package as part of the ACOLA Horizon Scanning Series – The Internet of Things. This work package addresses "Opportunities – Enabling Infrastructure and emerging technology" and examines the implementation of IoT through a smart cities and regions lens, with particular consideration of the questions below.

- What is the importance of satellite and space technology in the context of the IoT?
- What does the enabling and emerging technology in this area look like in two, five and ten years' time (in the context of the IoT)? This includes considerations of high altitude, sub-space platforms like HAPS and drones.
- Where are the opportunities and challenges (economic, commercial, environmental and sustainable) for Australian cities and regions with regards to IoT and satellite and space technology?
- What practical measures are required to support implementation and to realise the opportunities?
- Where can Australia be a leader in satellite and space technology with regards to IoT?

The importance of satellite and space technology in the context of IoT

For many IoT applications such as home appliances, smart city, smart grid and urban industrial settings IoT networks can be connected using local and wide area networks (LAN's, WAN's), WiFi, Bluetooth, cellular and power-line technologies. However, in remote areas and for moving objects, such as planes, boats and long-haul road transport, these terrestrial networks are not available. In Australia wireless terrestrial mobile coverage now reaches 99 percent of the population, but only around 30% of the landmass[1]. In disaster, emergency or defence situations there may be a requirement for communication and internet services, which can be integrated with terrestrial LTE or 5G networks, to be rapidly provided in 100-200 km radius hot-spots. For these applications' high altitude pseudo satellites, stratospheric drones and stratospheric balloon technologies are emerging.

[1] www.telstra.com.au/coverage-networks/our-coverage and www.optus.com.au/shop/mobile/network/coverage

Low-earth orbit satellite constellations

Low-earth orbit (LEO) satellite constellations can provide critical infrastructure to support IoT services particularly for remote areas (e.g. agriculture, resources, ocean, forest) and moving objects (e.g. cars, boats, planes) where access to terrestrial fixed wireless network is not available.

For remote areas and moving objects, LEO satellite constellations offer the advantages of global coverage, low signal delay times (quantified by the return trip time), low signal loss and low cost when compared to the traditional geostationary earth orbit (GEO) satellite systems. This allows satellite IoT terminals to be small-size, long-life and low power consumption[2].

High-Altitude Pseudo Satellites and Stratospheric Drones

In addition to LEO satellite constellations new technologies are emerging for which can sit at even lower altitude than LEO satellites and provide LTE and 5G telecommunications base station over fixed locations and earth observation surveillance.

What does the enabling and emerging technology in this area look like in 2, 5 and 10 years in the context of IoT, including for high altitude, sub-space platforms such as HAPS and drones.

Over the next two to five years the industrialisation of the LEO will see constellations of satellites providing internet and sensor network connections that will provide critical communications infrastructure to enable the IoT. High-Altitude Pseudo Satellites (HAPS) and stratospheric drones will allow LTE and 5G services to be established over disaster zones and also remote locations. Improvements in battery storage and solar power systems should extend the current flight duration of 25-30 days to 100-120 days so that several HAPS or drones can provide annual coverage.

Emerging infrastructure in LEO from satellite constellations.

Examples of emerging infrastructure in LEO include:

- The Iridium NEXT constellation of 66 satellites, completed in February 2019 will provide broadband, IoT and hosted payloads services. The constellation has pole-to-pole coverage of the planet comprising six polar orbiting planes, each containing 11 crosslinked satellites which create a web of coverage around the Earth[3]. The constellation, together with a small-form-factor transceiver known as the Iridium Certus^{SM} 9770, enable consumer and industrial applications that are portable and IoT-friendly, optimized for small size and low cost with higher speeds than in the past.
- SpaceX has launched the first 60 satellites of the planned Starlink constellation. These first satellites are understood to not be connected via inter-satellite laser link which is a planned capability for satellites in the future planned launches[4] SpaceX has applied for license approval to launch 4,409 satellites, followed by another constellation of 7,518 which will eventually form the full Starlink constellation. SpaceX has not revealed full details of its plans however it is understood the spacecraft will fly in a relatively low orbit

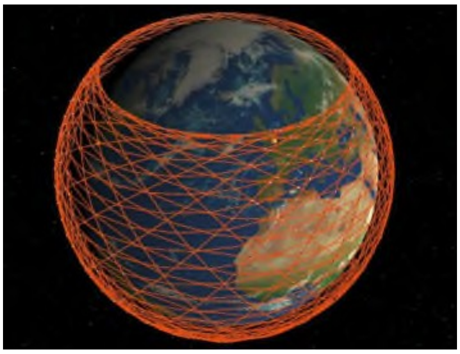

Figure 1 Illustration of SpaceX constellation of Thousands of Starlink satellites. Credit to Mark Hadley University of London

[2] Qu et al., 2017 LEO Satellite Constellation for Internet of Things. IEEE Access, Volume 5 https://ieeexplore.ieee.org/document/8002583/figures#figures

[3] http://investor.iridium.com/2019-01-11-Iridium-Completes-Historic-Satellite-Launch-Campaign

[4] Aude Vignelles, Australian Space Agency, pers.comm July 2019

above the planet and beam internet coverage to the ground providing service to all areas of the globe. There are also no public details of the end-user antenna which is a crucial sub-system of any LEO internet constellation. The constellation is designed to provide coverage to rural or remote areas as well as provide another internet service option to customers. Initially SpaceX intends to target the high-end gaming market.

- Australian-based, start-up Myriota has IoT data terminals that connect directly to a constellation of proprietary nanosatellites that have been trailed for water tank monitoring and defence applications[5]. The company aims to build a constellation of 50 nanosatellites. Currently it has four satellites in orbit.
- Australian-based, start-up Fleet Space Technologies Pty Ltd has IoT data terminals which will be linked to planned constellation of nanosatellites. In the Fleet system design the IoT sensor and devices link to a terrestrial base station and the base station connects to the satellite. Fleet has launched first satellites and is trialing application of its technology in the agricultural market[6].

Emerging technology from high-Altitude Pseudo-Satellites (HAPS) and stratospheric drones

New technologies are emerging for which can sit at even lower altitude than LEO satellites and provide LTE and 5G telecommunications base stations over fixed locations and payloads for earth observation surveillance. This includes High Altitude Pseudo Satellite (HAPS) or stratospheric drones. These technologies operate at around 20-25km altitude in the stratosphere. The stratosphere offers a lower wind environment with predictable and steady currents. The stratosphere above northern Australia is well known to have predictable and steady currents.

At these low altitudes HAPS and stratospheric drones can deliver LTE and 5G telecommunications network coverage as well as earth observation payloads. The advantages of HAPS include seamless interaction with terrestrial 5G and LTE networks and for rapid deployment of a communication cell with 125-200 km diameter.

Examples include:

- Australia is already home to Airbus' first global launch and retrieval site for its Zephyr HAPS in Wyndham WA. The site was chosen due to the stable and predictable currents in the stratosphere above central and the northern central Australian region (Figure 1.) Zephyr has a 25m wingspan and 10 battery packs (the size of large laptop) each made up of strings of 172 lithium batteries with silicon anodes. The drone has two propellers, a mission port for cameras and payload, a carbon fibre frame and weighs 60 kg. It can be launched by 5 people on a standard aircraft runway and takes 8 hours to climb to its flying altitude of 20-25km. It lands back on its launch rails. Licensing and regulation in Australia is authorized by CASA. Power comes from a 3kW solar array that powers the avionics, payload and propeller engines. It has 35W of power available at night and 15W during the day[7].

Figure 2 Airbus Zephyr Stratospheric Drone

[5] https://myriota.com/news/

[6] https://www.fleet.space/news

[7] Airbus information provided publically at the opening of the Wyndham, WA, launch and retrieval site.

- SoftBank subsidiary HapsMobile a joint venture established in 2017 by SoftBank and U.S. aerospace company AeroVironment, is developing a high altitude pseudo satellite called HAWK30 which can provide LTE and 5G services over 200m in diameter[8] (Figure 2). The Hawk30 is 78 meters long, with solar panels and 10 propellers mounted to its wings. It flies at around 110 kilometers per hour at > 20 km altitude with a flying time of several months.

Figure 3 HapsMobile's Hawk30 High Altitude Pseudo Satellite

Emerging Technology for high-altitude balloons

Loon, one of the Alphabet subsidiaries that have spun out of Google is developing stratospheric balloons which travel at around 20 km altitude in the stratosphere and provide LTE communications on the ground for internet connectivity[9]. The balloon uses the predictive models of the stratospheric winds to move in the intended direction. The models allow them to rise and fall to take advantage of different wind speeds and directions within the stratosphere. Loon has tested its technology in Australia.

Figure 4 Loon's stratospheric balloon technology

Where are the opportunities and challenges for Australian cities and regions with regard to IoT and satellite and space technology?

Significant opportunities exist for Australia to adopt satellite and space technology including stratospheric drones and balloons to enable internet connectivity over 70% of the landmass not serviced by terrestrial fixed and wireless networks. These opportunities include:

- Critical infrastructure to support automation, robotics and IoT application in agriculture, mining and energy and long-distance transport.
- Critical communication networks in regional Australia including land, marine and airspace.
- Establishment of ground infrastructure for launch and retrieval sites for HAPS, stratospheric drones and stratospheric balloons servicing the Asia Pacific region.
- Development of sovereign industrial capability and commercial expertise in nanosatellite and small satellite constellations and IoT services for remote areas.
- Development of manufacturing capability for small satellites.
- Further development of access to space for launch and retrieval sites for HAPS and stratospheric balloons to service the Asia-Pacific region.
- Establishment of access to space launch site and sovereign small rocket capability for launch of small satellites for polar and equatorial orbits.

Challenges for Australia to realise these opportunities include:

- Spectrum allocation and sharing for terrestrial wireless networks and space-based infrastructure. The Australian Communications and Media Authority has recently called for submissions to guide its next 5

[8] https://www.avinc.com/about/haps

[9] https://loon.com/technology

year plan[10].

- Global competition in establishing the space-based internet and network infrastructure is well advanced and attracting significant infrastructure. Australia has yet to establish a globally competitive foothold in this fast-growing area. The risk if Australia falls behind is that we become a taker of imported technology and services and fail to develop our sovereign capability.
- While Australia is proving an attractive location for global launch of HAPS and stratospheric balloons we have yet to establish access to space for small rockets and small satellite launch.

What practical measures are required to support implementation and to realise the opportunities?

Practical measures to support implementation and realise the opportunities are:

1) Completion of the Geoscience Australia led augmentation system to provide 10cm positioning accuracy across our sovereign land, marine and airspaces and precise positioning of 3cm in our cities using additional correction to the GPS signals using the mobile phone network. This infrastructure provides a critical platform or automation, IoT and smart city development[11].
2) ACMA to continue to consider spectrum allocation that supports terrestrial and space-based communication infrastructure.
3) CASA and the Australian Space Agency to continue to collaborate on the legal and regulatory framework above and below 20km for access to the stratosphere and space.
4) Progress the Australian Space Agency 10 year strategy "Advance Space"[12] to open doors internationally, increase national capability, promote responsible regulation risk management and culture and inspire and build a future workforce.

Where can Australia be a leader in satellite and space technology in regards to IoT.

Australia can be a leader in the use of satellite and space-based technology to enable automation of in our remote areas such as our agriculture, mining and resources, marine surveillance and monitoring and environmental monitoring.

Australia's geography means that we are well positioned for providing access to space for launch and retrieval of HAPS and balloons as well as small rockets for launch of nanosatellites and small satellites into polar and equatorial orbits.

Australia has the capacity in the next 10 years to develop the full value chain of design, manufacture, qualify, launch and operate space-based technology to support the IoT services sector.

[10] https://www.acma.gov.au/theACMA/draft-five-year-spectrum-outlook-2018-22

[11] https://www.ga.gov.au/scientific-topics/positioning-navigation/positioning-australia

[12] https://www.industry.gov.au/data-and-publications/australian-civil-space-strategy-2019-2028