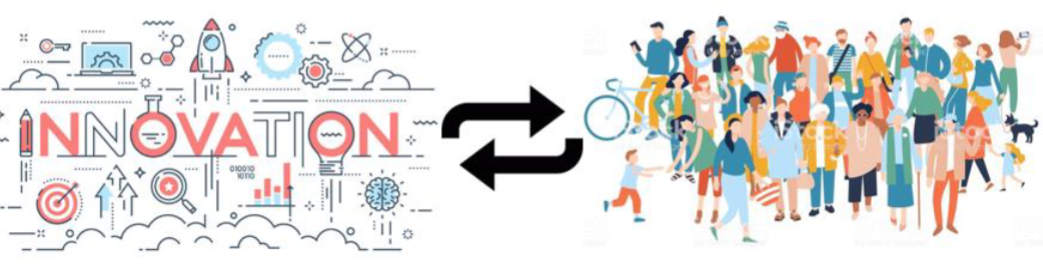
**ENGG3000 Perspective Piece**

*Interdependency of culture, society, and technological innovation*

**EE4 Embedded Systems and Edge Computing**: With the proliferation of IoT, there's a growing need for processing data at the source, leading to advances in embedded systems and edge computing.

**Infrastructure Needs**: Many regions need better roads, schools, hospitals, and public transportation.

1. *Abstract/Executive Summary*

Advancements in microelectronics have enabled fast, compact, and cost-effective embedded devices. These systems can collect data, processing, and transmitting it over a network. Devices like these make up the ‘Internet of Things’ (IoT), a series of interconnected devices and systems that collect and process data. More and more data is being produced by imbedded systems designed for monitoring and data acquisition.

Development in IoT and edge computing will have a significant impact on the future of smart infrastructure. Many cities face issues with strained healthcare resources, public transportation limitations, inconsistent education standards, and unmaintained infrastructure. The purpose of this piece is to discuss the advantages and challenges of implementing a system of this scale and explore how it could be better utilised to improve public infrastructure and services.

1. *Introduction/Background*

This perspective piece aims to explore and highlight the impact of IoT, embedded systems, and edge processing on public infrastructure and services. With limited resources in a struggling economy its more important than ever to have accurate and actionable data available to make the most of available resources.

By 2025 an estimated 75% of enterprise-generated data would be generated outside of centralised data centres [1], its important to understand the benefits and drawbacks of edge processing and how it will impact the world around it. Edge processing enables many more devices to be connected to a network, as they either send their data to an ‘edge gateway server’ nearby or process the data themselves. This makes it much more efficient to run more devices. These kinds of gateways can serve small areas, but Fog-nodes are a step above. Fog-nodes are on the scale of smart buildings, cities, or even smart utility grids. And put the processing power ‘near’ but not necessarily at. Consider a smart city where data can be used to track and analyse the public transport system with traffic data, municipal utilities, services, and long-term planning. Its these sorts of systems that control large scale networks.

These large-scale processing systems businesses and cities to monitor and make informed decisions based on the data recorded. These would be used to enhance public transport services, manage resources and patient data for hospitals, monitor public infrastructure for damage. Smaller edge processing deployments would handle things like wearable technology and user-friendly devices.

1. *Body Discussion*

Embedded systems and ‘smart devices’ are becoming more and more predominant in every aspect of life. With the vast amount of network compatible devices being connected, more information is available through the network. Leveraging the developing 5G Network, these devices can process data at the point, and relay that through edge computing to a central server. This availability of data allows processed data to be relayed back to the user much faster, increasing what is called ‘data availability’. Increased data availability for both individuals as well as companies means informed decisions can be made with the data in mind. Other software and hardware can leverage this data to influence its decision making also. With many communities encountering un-maintained infrastructure, education inequality, struggling healthcare, and inefficient public transport, it is important to explore how this technology can be applied in these sectors to make the most of limited resources.

## 1. Public Infrastructure and Industrial Applications

Embedded systems have a major role to play not only in maintenance, but also in energy efficiency, security, and automation. One of the most important uses of embedded devices in infrastructure includes roads and bridges. Both are subjected to a variety of weather conditions and are repeatedly subject to differently displaced and weighted loads. They require constant maintenance, and its is difficult for an individual to determine where a road or bridge may fail in the future. Embedded systems can be deployed to gather data on the weather conditions for a certain area, and sensors in the road or bridge can determine parameters such as strain, humidity, or vibrations. This data can be processed at a local edge processing point and relayed for further processing, allowing analysis of data over a long period. This information can be used to determine likely points of failure, or actively shut down an area if a fault or hazard is detected.

A real-world example of embedded devices in action can be seen in Gliwice Bridge, in Poland [2]. A European project named Infrastar is using embedded systems to monitor load, temperature, strain, deflection, and humidity. These measurements combined with ultrasonic sensors can determine the operational changes, corrosion, static deformation, propagation of cracks, and strain. Infrastar uses this data to monitor the health of the bridge from multiple readings, and to make informed decisions on repairs and maintenance. They hope to apply this technology further in any concrete and steel structure. IoT and embedded systems supported by an edge computing network can make significant difference in the way that public infrastructure is designed. To ensure longevity of things such as roads, highways, bridges, and buildings, monitoring systems such as this can be installed to make more efficient use of resources and minimise downtime.

This same approach can be taken with industrial applications, using sensors and gauges to determine the health of machines being used in production. Using this data downtime can be avoided with more efficient repairs.

## 2. Healthcare and Patient Monitoring

There are a number of challenges faced by healthcare systems the world over. Strained resources especially during the COVID-19 Pandemic as well as record low staff and staff compensation, have meant that healthcare systems have been struggling to keep up.

Monitoring a patient’s health was previously limited to visits and telecommunication. A healthcare professional can only take limited readings during a visit and can’t determine the patient’s condition over telecommunications. Embedded systems in the form of wearables, small form factor appliances, and even implants, can take measurements while the patient is at home. Smart watches such as the Apple Watch or the Fitbit have also adopted this sensor technology and can provide similar data while acting as a wearable device for the user. These devices can even send alerts to medical professionals and family members in the event of emergencies. Doctors can track patient’s adherence to treatment plants, if there’s any need for immediate attention, and help schedule appointments more efficiently for detailed checkups.

Apart from medical monitoring, location tags can easily be added to medical equipment for real time tracking, and in future could even determine the operation of the device. IoT hygiene monitoring devices can monitor contaminants and prevent patients from getting infected in hospital environments. Additionally, this data when accumulated over time and processed, can assist in diagnosis through data analysis of previous patients. It could even inform doctors and patients of risks of developing conditions or problems.

Access to this data is a powerful thing for patients to have, as it gives them more agency over their own health and makes them more confident that treatment is helping. Access to this information also helps Health Insurance Companies determine fraudulent claims and helps patients making claims to provide evidence for their conditions. The data allows both claimant and company to have a clear understanding of the decision-making process, and ensure claims are paid out properly.

## 3. Education

Especially after the COVID-19 Pandemic, education has had to make a shift to delivery of resources through the internet. Zoom calls, recorded lectures and online collaboration tools have made up a more digital basis for education in the modern day. With this reliance in the network, the IoT is making a larger impact on the way education is conducted than ever.

IoT is transforming how students engage with learning content. Laptops, tablets, and phones allow students to access a variety of content and data, as well as manipulate that data themselves. Notes can be integrated with the internet for sharing purposes and include simulations or applications that would be impossible without internet access. The IoT also enables access to devices connected to the network in a different location. Students can access computer systems and monitor equipment remotely which is particularly useful in the sciences or engineering.

Teachers can also use this technology to effectively assess their students, and determine through their activity who need additional resources or guidance and who is doing well. Digital systems also allow teachers to more effectively convey information, hosting live streams and remote teaching activities for their students. This allows a similar amount of interaction to that of an in-person session, and gives students who are unable to attend physically a similar experience. The session recorded through embedded devices can also be made available through the network for students to review and rewatch for better understanding.

A major concern in this case is security and privacy. With students looking for more services online its possible there could be leaks in personal information. Educating students in cybersecurity and remaining safe online is an important thing to reinforce. Overall, this increase in connectivity and access to resources from a great distance enables people to learn from remote locations and at their own pace. Its also important to ensure students are being safe online.

## Public Transportation

Public transportation is a complex and delicate system, and its important for any developed area to have efficient public transport. Its important to have as much data on the effectiveness of the system, so issues can be resolved, and services improved. Embedded systems and edge computing has drastically improved services and data collection for public transport. Sydney’s own public transport network uses the ‘Opal’ system, which is used to calculate routes and charge accurate rates to passengers. An embedded system is used in each terminal to read cards and begin a route at that destination, when the user taps off at a different terminal the route is ended, and the rate calculated. This technology can be used to determine common routes and occupation rates of each bus, train or tram. This information can be used to make timetables, rework bus routes, and predict maintenance of the transport system more efficiently.

These embedded systems also enable service vehicles to be tracked and enable live timetables with delays accounted for available for passengers. Services such as the Opal app allow passengers to monitor and schedule different services together with live delays and schedule changes. Anyone with a smart phone and network connection is able to access this information and plan their routes. However, this information is only as good as it’s accuracy, apps can sometimes have downtime, and if the schedule is not updated people can be misled.

1. *Conclusion/Impact*

The impact of IoT and the shift to and Edge Computing model have drastically altered the way data is collected and processed. The data made available through these developments have aided a struggling global economy, enabled more efficient use of resources, taken pressure off of essential services, and changed the way we learn and connect as people. While the technology is not fully developed, over the next few years we will expect to see a much stronger and larger IoT network develop. Considerable challenges concerning safety and consistency lie ahead, but from what’s been implemented so far these challenges can be overcome with time. These devices will be everywhere, where once we would have had to flick a switch, the lights now turn on by themselves. The watch on your arm tells you how well you slept, your alarm went off early to account for high traffic on your route to work, these sorts of things will become common place. Theres no doubt it will change the way we interact with the world around us.

[1] S. J. Bigelow, “What Is Edge Computing? Everything You Need to Know,” *SearchDataCenter*, Dec. 2021. (<https://www.techtarget.com/searchdatacenter/definition/edge-computing>)

[2]J. Chakraborty, A. Katunin, P. Klikowicz, and M. Salamak, “Embedded ultrasonic transmission sensors and signal processing techniques for structural change detection in the Gliwice bridge,” *Procedia Structural Integrity*, vol. 17, (<https://www.sciencedirect.com/science/article/pii/S2452321619302550>)

[3] Wipro, “IoT in Healthcare Industry | IoT Applications in Healthcare - Wipro,” *Wipro.com*, 2019.

(<https://www.wipro.com/business-process/what-can-iot-do-for-healthcare-/>)

[4] Intuz, “IoT In The Education Industry: Embracing The New Way Of Learning,” *www.linkedin.com*, Feb. 28, 2023.

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