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CITS 5506
The Internet of Things
Lecture 06

Components of IoT (Continuation)
Research Project (Bridge Health Monitoring)
Smart Products

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Components of IoT

- **Sensors**
- **Connectivity**
- **Platform**
- **Analytics**
- **User Interface**

Components of IoT

Connectivity

Connectivity : Low Power Wide Area Networks

- **SIGFOX (**https://www.sigfox.com)

Sigfox is a French company founded in 2009 that builds wireless networks to connect low-energy objects such as electricity meters, smart watches and washing machines, which need to be continuously on and emitting small amounts of data**.**

- Range 10 km (urban), 40 km (rural)
- Learn and Build your own IoT Product utilizing Sigfox

  https://build.sigfox.com/

Connectivity : Low Power Wide Area Networks

- Sigfox employs a proprietary technology that enables communication which uses 868MHz in Europe (ISM band) and 902MHz in the US (again ISM Band)*.
- It utilizes a wide-reaching signal that passes freely through solid objects, called "ultra narrowband" and requires little energy, being termed "Low-power Wide-area network (LPWAN)".
- The signal can also be used to easily cover large areas and to reach underground objects.
- Sigfox has partnered with several firms in the LPWAN industry such as Texas Instruments, Silicon Labs and ON Semiconductor (produce IoT development kits).

* https://www.tesswave.com/what-are-the-ism-frequency-bands

LoRa: Long Range Low Power Wireless platform

- LoRa is a proprietary, chirp spread spectrum (CSS) radio modulation technology for LPWAN used by LoRaWAN, Haystack Technologies, and Symphony Link.
- LoRa is a patented technology developed by Cycleo (Grenoble, France) and acquired by Semtech in 2012.
- LoRa uses license-free sub-Gigahertz radio frequency bands like 169 MHz, 433 MHz, 868 MHz (Europe) and 915 MHz (North America).
- Range 5 km (urban), 20 km (rural)
- A comparative study of LPWAN technologies for large-scale IoT deployment (https://www.sciencedirect.com/science/article/pii/S2405959517302953)

Weightless (Wireless Communication)

- Weightless is the name of a set of LPWAN open wireless technology standards for exchanging data between a base station and thousands of machines around it. These technologies allow developers to build Low-Power Wide-Area Networks (LPWAN).
- 10km range
- Cambridge, UK based company

https://www.iotglobalnetwork.com/companies/single/id/954/weightless

Weightless (Wireless Communication)

- Weightless is managed by the Weightless SIG, or Special Interest Group.
- The intention is that devices must be qualified by the Weightless Special Interest Group to standards defined by the SIG.
- Patents would be licensed to those qualifying devices; thus, the protocol whilst open, may be regarded as proprietary.

RPMA

- Random phase multiple access (RPMA) is the trade name given to a low-power wide-area channel access method product being sold by the company Ingenu, formerly On-Ramp Wireless.
- It is meant to be used for machine-to-machine (M2M) communication on the Internet of Things (IoT).
- RPMA covers rural Texas oilfields with 450 square miles per tower (from RPMA website).

https://www.ingenu.com/

https://www.ingenu.com/technology/rpma/

RPMA

- RPMA is currently used in dozens of private networks worldwide. The 2.4 GHz spectrum is available worldwide and is cost-free to use.
- RPMA access points may cover up to 300 square miles. It would take 30 cellular towers to cover the same area.
- Ingenu, who owns RPMA, reportedly has some access points covering as many as 450 square miles each.

Emerging 5 G Networks

- The biggest input to IoT may come from cellular community. 3 GPP is now working on 5G standardization. The group has the experience of standardizing 3 G and 4 G.

- Cellular is becoming increasingly attractive for supporting large-scale IoT installations due to:
  - wide coverage
  - relatively low deployment costs
  - high level of security
  - access to dedicated spectrum
  - simplicity of management

Emerging 5 G Networks

- However, LTE networks have not been designed keeping in view IoT devices, which can be event driven.

- Therefore, several improvements have been initiated in 3GPP aiming to augment LTE to become more suitable for IoT applications.

- The number of connected machines are expected to grow dramatically-- up to 30,000, maybe 60,000 devices in a single cell– so LTE technologies require respective mechanisms to handle a very large number of devices.

** LTE (Long Term Evolution) is a 4 G wireless standard for high Bandwidth.*

Emerging 5 G Networks

- Typical IoT data transmissions are infrequent, small, and require simplified *signaling* procedures for connection establishment to offer energy consumption saving for such devices.

- If technology and data plans are affordable, cellular technology can support IoT due to its global availability and considerable reliability.

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NB-IoT

- NarrowBand IoT (NB-IoT) is a Low Power Wide Area Network (LPWAN) radio technology standard developed to enable a wide range of devices and services to be connected using cellular telecommunications bands

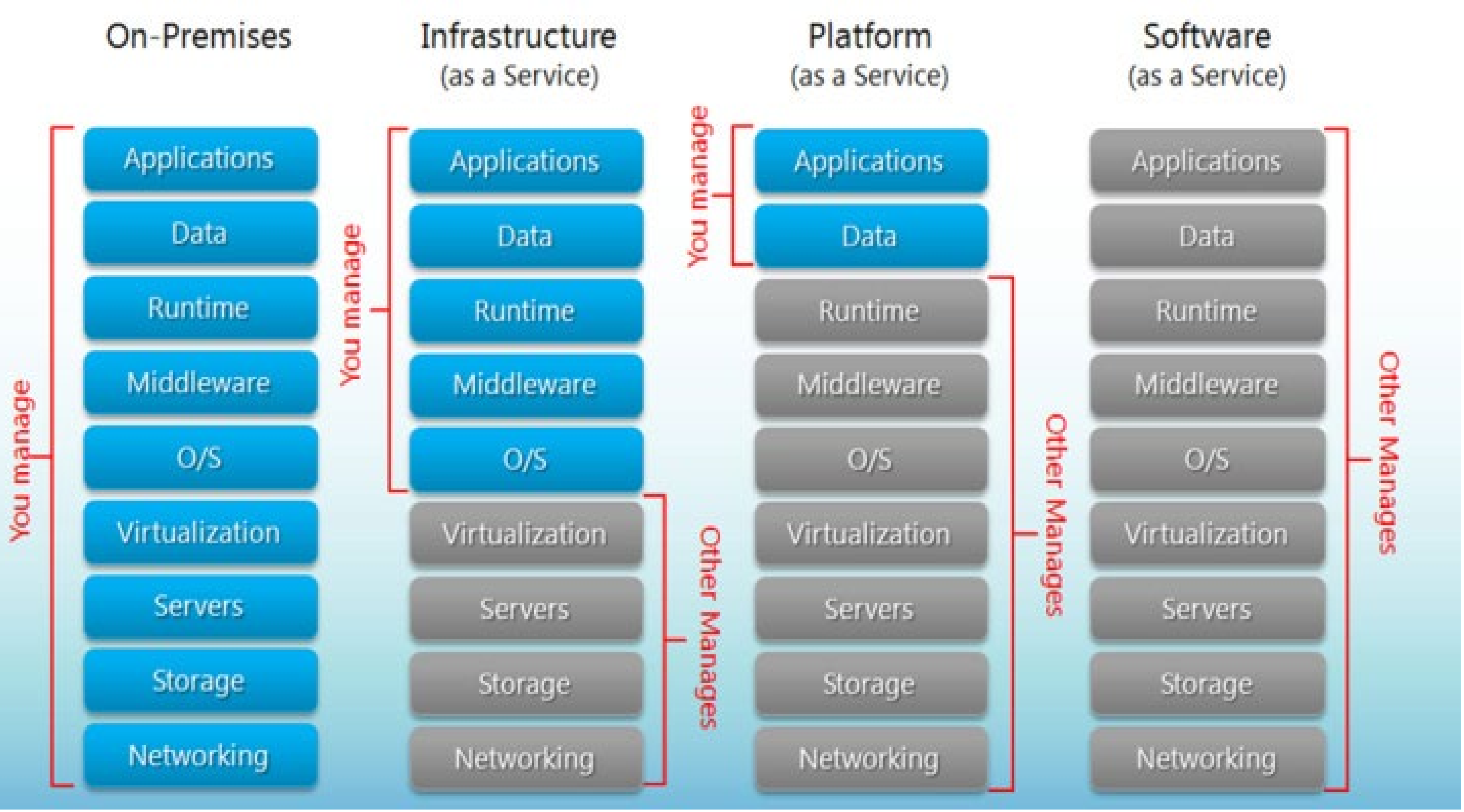
- NB-IoT is a narrowband radio technology designed for the Internet of Things (IoT) and is standardized by the 3rd Generation Partnership Project (3GPP)

- Range 1 km (urban), 10 km (rural)

Platform

- The collected data needs to be stored and processed somewhere. Known as IoT platforms, these are typically cloud-based infrastructures which:
  - receive and send data via standardized interfaces, known as API (Application Programming Interface)
  - store the data; and
  - process the data
- Many commercial platforms are available today, e.g, Amazon Web Services (AWS), Microsoft Azure, IBM Watson, Google Cloud Platfrom, Oracle, Bosch, CISCO IoT cloud Connect, SAP etc etc

Comparison of Cloud Services



Middleware

- Middleware is a type of computer software program that provides services to software applications beyond those available from the operating system.
- Database access services are often characterised as middleware, e.g ODBC. Open Database Connectivity (ODBC) is a standard application programming interface (API) for accessing database management systems (DBMS). The designers of ODBC aimed to make it independent of database systems and operating systems.

Runtime

Runtime is also when a program is running. That is, when you start a program running in a computer, it is runtime for that program.

In some programming languages, certain reusable programs or "routines" are built and packaged as a "runtime library." These routines can be linked to and used by any program when it is running.

Software as a service (SaaS)

Recommended is scalable cloud solutions in a software-as-a-service (SaaS) model for IoT

Software as a service (SaaS) is a software distribution model in which a third-party provider hosts applications and makes them available to customers over the Internet like office365, Canva etc

SaaS is one of three main categories of cloud computing, alongside infrastructure as a service (IaaS) and platform as a service (PaaS).

PaaS (Platform As A Service)

- Used for applications, and other development, while providing cloud components to software.

- What developers gain with PaaS is a framework they can build upon to develop or customize applications.

- PaaS makes the development, testing, and deployment of applications quick, simple, and cost-effective

IaaS (Infrastructure As A Service)

- Self-service models for accessing, monitoring, and managing remote data center infrastructures, such as compute (virtualized or bare metal), storage, networking, and networking services (e.g., firewalls).

- Instead of having to purchase hardware outright, users can purchase IaaS based on consumption,

Analytics

- Data analytics needs to be applied to the data to get the insight from data.

- Big data analytics tools are generally available today, which stretch from simple statistical tools to more sophisticated machine learning approaches, with deep learning being the latest trend.

- Think of statistical tools finding you the known knowns in the data; machine learning finding the known unknowns; whilst deep learning is able to find the unknown unknowns like with generative adversarial networks (GANs).

Steganographic universal adversarial perturbations, Pattern Recognition Letters, Volume 135, Pages 146 - 152July 2020

User Interface

- User Interface is the component that how the data is presented to the final users.
- IoT product needs to have a very appealing user interface, both web based as well as smart phone or tablet based.
- There are many open-source as well as paying front-end products available today e.g, OpenRemote
    - OpenRemote is an open-source project, which integrates many different protocols and solutions available for smart building, and smart city automation, and offers visualization tools. (Wikipedia)
    - https://www.openremote.io/

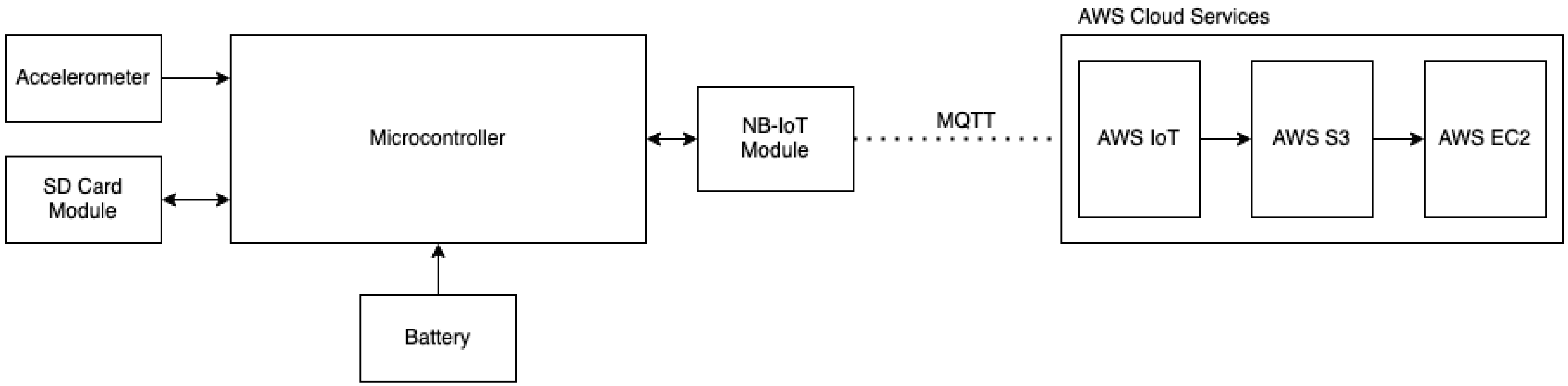
SMART PRODUCTS

Smart Tennis Sensor

Research Project : Bridge Health Monitoring using IoT

Develop IoT-based pipeline for cost effective, easy to install and timely collection, transmission and visualization of vibration response data that can predict the bridge health.

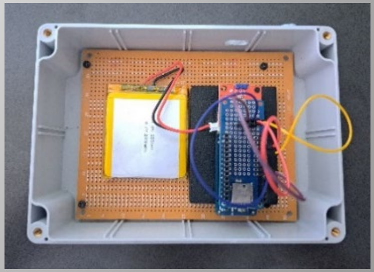
Block Diagram



ACCELEROMETER BOARDS

Three different platforms tested

- Libelium Waspmote microcontroller board
  - Discarded due to limited software libraries support and limited SRAM on the microcontroller
- RAKwireless WisTrio RAK5010
  - Discarded due to connectivity issues over the NB-IoT
- Arduino MKR NB1500
  - SD card shield and the ADXL345 accelerometer



DATA COLLECTION

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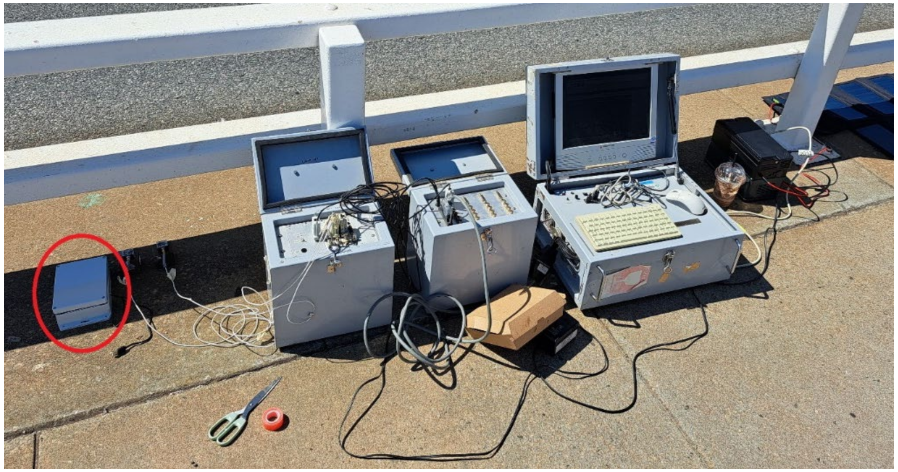
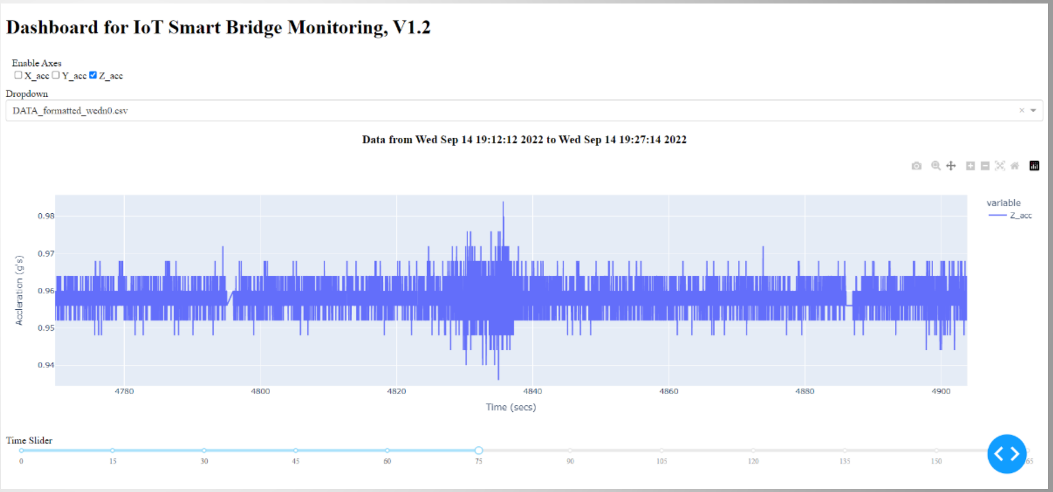


- Data collection in Sept, 2022 on the Stirling Bridge in Fremantle, Perth for 03 days

- Three modalities, visual (video) data, wired sensor data and data from the IoT prototype.

DATA COLLECTION

- The data collected by IoT system was sent using a MQTT broker over the Telstra network and received by AWS IoT core.
- Messages were published to a topic and then stored in a Simple Storage Service (S3) bucket.
- A dashboard was developed to display the incoming data using the Dash/Plotly python library with options of time sliding, zoom in and out, individual axis and multiple axes selection.



DATA TRANSMISSION

2kB messages can be sent reliably in approximately 1.5 seconds.

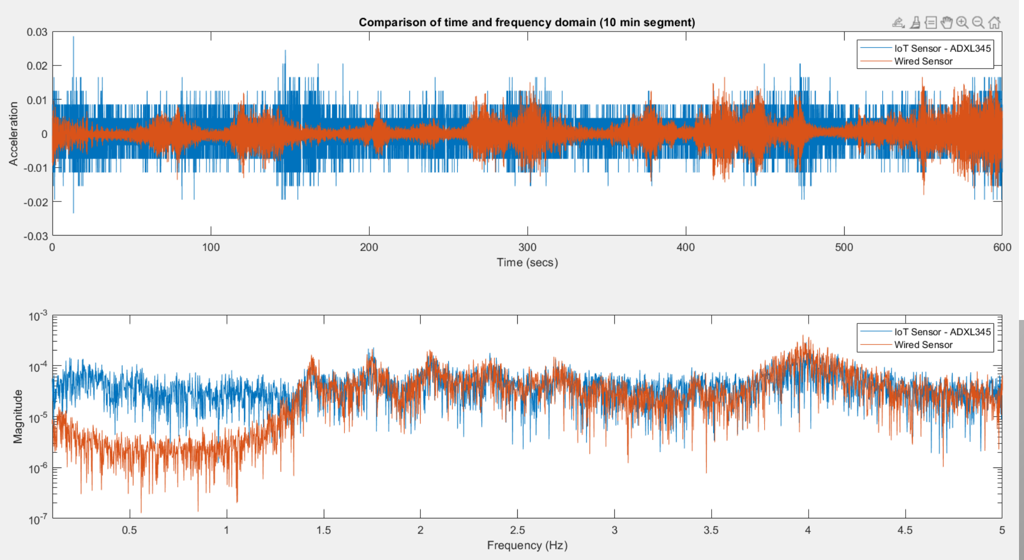
Experiments have shown that one minute of 3 axis (x, y, z acceleration) data requires 80 seconds to send to AWS

The recording and transmitting only Z-axis data of one minute duration takes 40 seconds to upload to AWS.

There is need to further investigate with aim to reduce data transmission through edge computing at the source.

DATA ANALYSIS

- The responses of digital IoT sensor (ADXL345) and the analog industrial wired sensor (Kistler 8330A3) were compared using the data collected from the Stirling bridge.
- A time domain analysis proved difficult due to synchronization issues in the two data sets, though it is obvious from following figure that both sensors had a similar time domain response.
- The frequency domain results do show similarities in the frequency and magnitude to the Kistler spectrum, particularly from 1.5 Hz to 5 Hz. Team felt need for sensitive accelerometer.



CONCLUSION

Successfully developed a hardware and software pipeline for collecting, transmitting and visualizing vibration response data that can aid in Structure Health Monitoring of the bridges.

The proposed system is cost effective, easy to install and has additional communication component that can quick transfer the data to the cloud for further analysis.

Along with the bridge health information, the system has the research potential to give valuable information related to traffic class, weight and traffic load.

PUBLICATIONS

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- Structural Health Monitoring and IoT: Opportunities and Challenges, International Conference on Intelligence of Things, Mar 21, 2022, Lecture Notes on Data Engineering and Communications Technologies, Springer.

  Access to Document: 10.1007/978-3-031-15063-0_1

- Development of IoT based Bridge Health Monitoring System: A Work in Progress, Australasian Transport Research Forum 2023

FUTURE WORK

- The IoT-based sensor data transmission to AWS needs further investigation to reduce the transmission rate. Edge computing at the source will reduce the amount of data to transmit to AWS, thus reducing the transmission cost and energy consumption.

- The above research work need to be in line with bridge health monitoring parameters such as shifts in the fundamental frequency etc.

- The future research work further encompasses comparison of digital accelerometer against analog wired accelerometer.

Smart City

Smart Products – Transforming Businesses

- Conventional Products were composed solely of mechanical and electrical parts in the past.

- But now Products have become complex systems that combine
  - hardware
  - sensors
  - data storage
  - Computing entity
  - software
  - connectivity

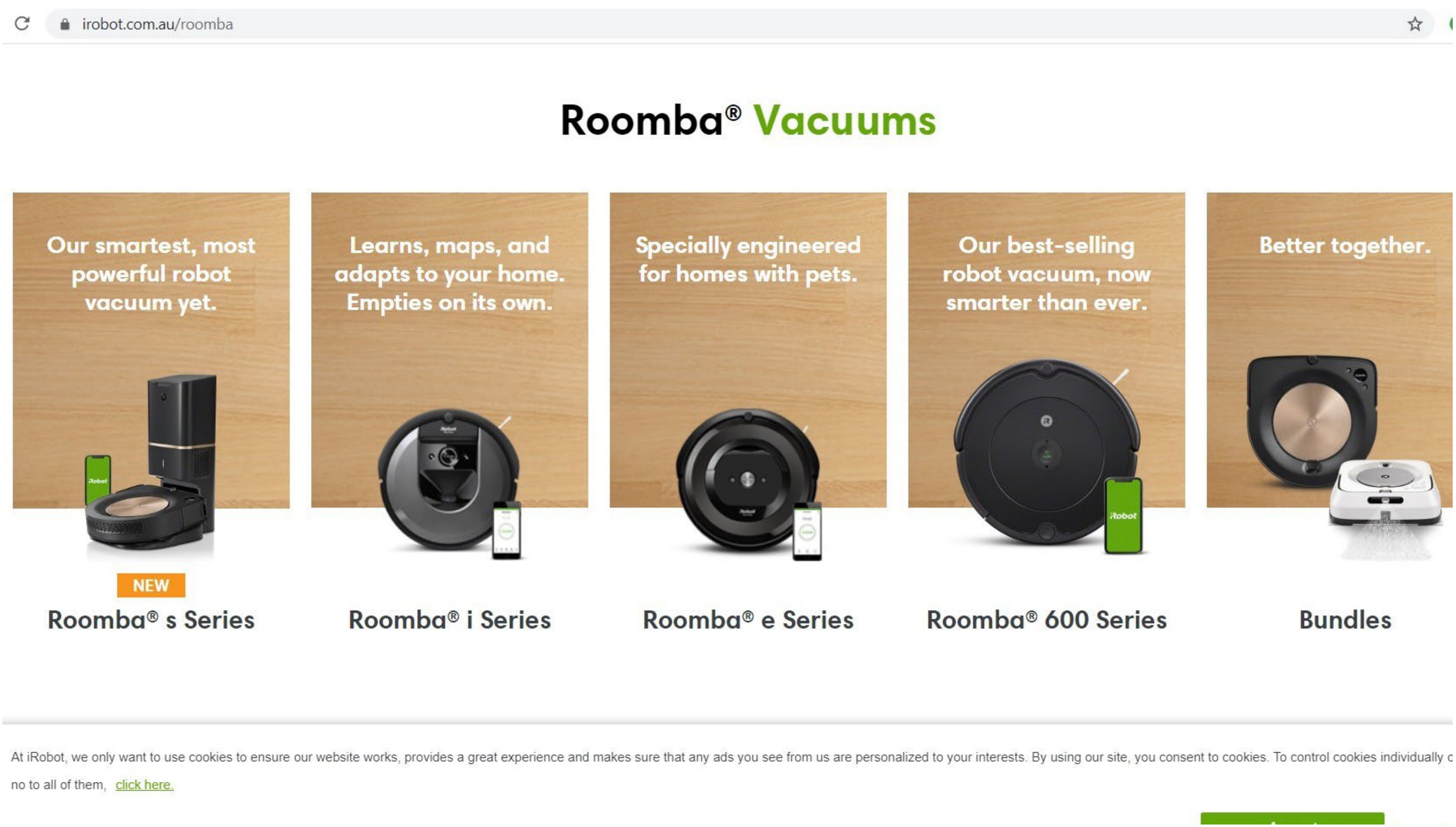
Smart Products – Transforming Businesses

Smart, connected products offer opportunities for

- New functionality
- Far greater reliability
- Much higher product utilization
- Capabilities that cut across and transcend traditional product boundaries.

IoT Applications: Smart Vacuum Cleaner

Robotic Vacuum Cleaners



Spying robot vacuum cleaner

https://7news.com.au/technology/be-very-wary-spying-robot-vacuum-sparks-expert-warning-on-common-household-items-c-12232066

Waymo – Formerly Google self-driving car project

Smart Products – Transforming Businesses

- The changing nature of products is also disrupting value chains, forcing companies to rethink and retool nearly everything they do internally.

- The idea of the value chain is based on the process view of organizations, the idea of seeing a manufacturing (or service) organization as a system, made up of subsystems each with inputs, transformation processes and outputs.

Smart Products – Transforming Businesses

- Inputs, transformation processes, and outputs involve the acquisition and consumption of resources – money, labour, materials, equipment, buildings, land, administration and management. How value chain activities are carried out determines costs and affects profits.

- These new types of products alter industry structure and the nature of competition, exposing companies to new competitive opportunities and threats. They are reshaping industry boundaries and creating entirely new industries.

Smart Products – Transforming Businesses

- Smart, connected products raise a new set of strategic choices related to
  - How value is created and captured
  - How the huge amount of new (and sensitive) data they generate is utilized and managed
  - How relationships with traditional business partners are redefined
  - What role companies should play as industry boundaries are expanded

Smart Products – Transforming Businesses

- What makes smart, connected products fundamentally different is not the internet, but the changing nature of the "things."

- It is the expanded capabilities of smart, connected products and the data they generate that are ushering in a new era of competition.

Smart Products – Transforming Businesses

- Before the advent of modern information technology, products were mechanical and activities in the value chain were performed using manual, paper processes and verbal communication.

- The first wave of IT, during the 1960s and 1970s, automated individual activities in the value chain, from **order processing and bill paying to computer-aided design and manufacturing resource planning**. This resulted in increase in productivity.

Smart Products – Transforming Businesses

- The rise of the internet, with its inexpensive and ubiquitous connectivity, unleashed the second wave of IT-driven transformation in the 1980s and 1990s.

- This enabled **coordination and integration across individual activities; with outside suppliers**, **channels, and customers; and across geography**. It allowed firms, for example, to closely integrate globally distributed supply chains.

Smart Products – Transforming Businesses

- The first two waves gave rise to huge productivity gains and growth across the economy. While the value chain was transformed, however, **products** themselves were largely **unaffected**.

- Now, Information Technology is becoming an integral part of the product itself. Embedded sensors, processors, software, and connectivity in products, data storage and analysis, resulting in improvements in product functionality and performance.

- Massive amounts of new product-usage data enable many of these improvements.

Smart Products – Transforming Businesses

- There will be new and better products.

- In addition, production process will alter by changing product design, marketing, manufacturing, and after-sale service and by creating the need for new activities such as product data analytics and security.