A Cost Effective Communication Mechanism for Underground Mine Internet of Things

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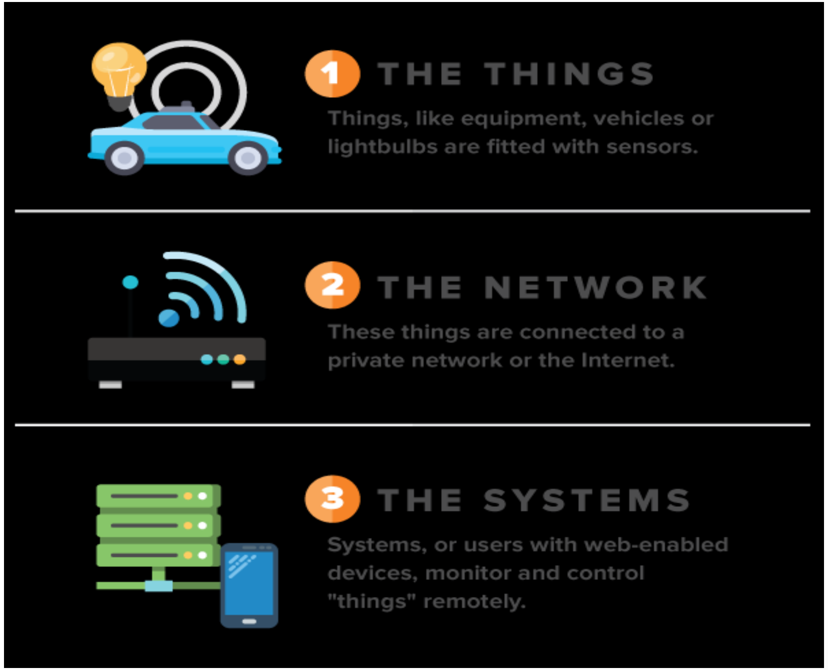
IoT and MIoT

- The actual idea of connected devices has been around since the 70s.
- The idea was often called “embedded internet” or “pervasive computing”.
- The actual term “Internet of Things” was invented by Kevin Ashton in 1999.
- Internet of Things for Mining – Mine IoT was first discussed in the late 2000s and became highlighted in recent years.
-

Three Layers of IoT

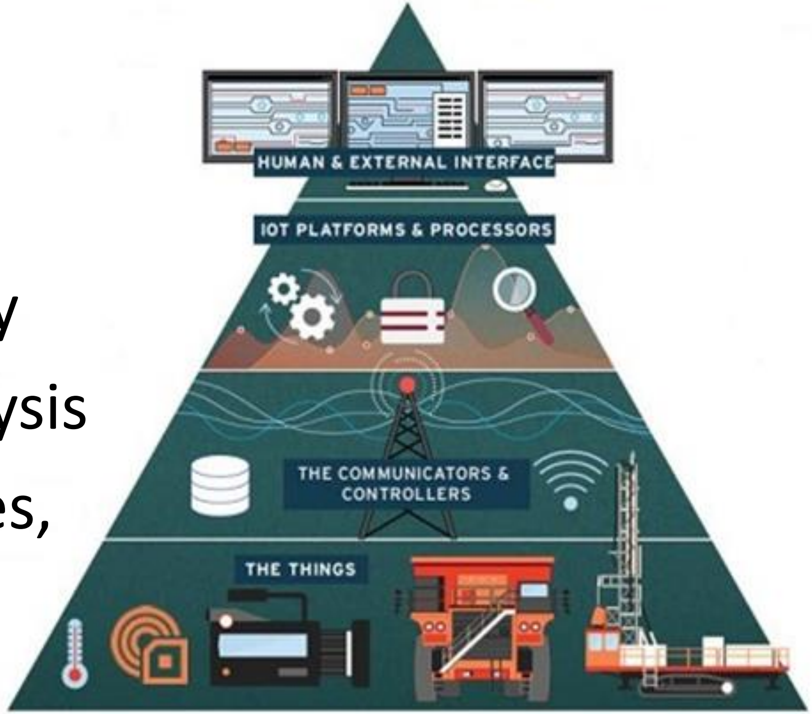
There are three layers of IoT:

- perception layer (extension of human senses)
  - sensors
- network layer (like human nerves that can bring data to the brain)
  - communication
- application layer (equivalent to the human brain which can analyse data and make decisions)
  - analytics & feedbacks



Benefits of Mine IoT

- Enables real-time analysis
- From reactive maintenance to proactive maintenance
- Improves safety & productivity
- Enables big “smart” data analysis
- Autonomy and smart machines, toward machine-only future
- And more …



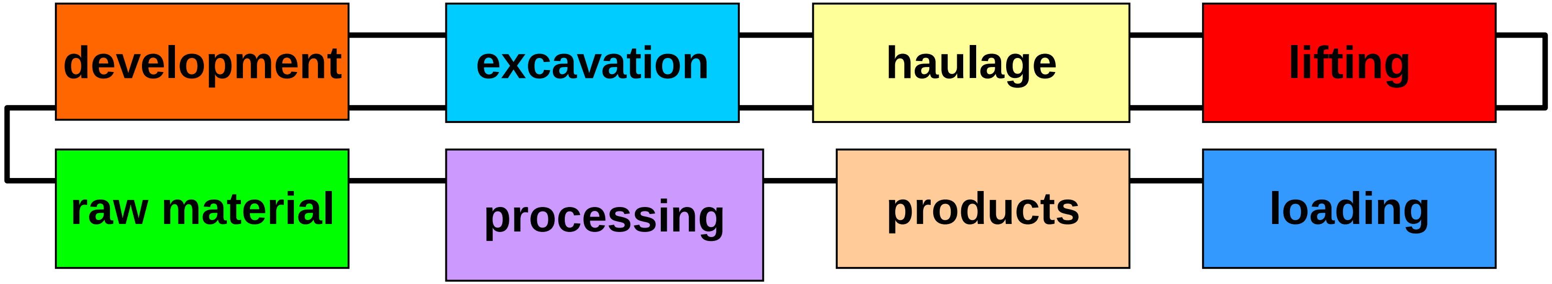
Kent, 2011

Challenges

- Sensing methods
- Sensing networks
- Software integration
- Information fusion
- Interface
- Standards

- Environment

Perception – the Things



- Ventilation
- Drainage
- Power Supply
- Pressure Supply
- Safety Management
- Mine Stress
- Fire Proofing
- Dust Control
- . . .
- . . .

Communications

- Wired
  - Ethernet
  - Leaky feeder
  - Optical fibre

- *They cannot connect to all these small devices directly everywhere underground - the complexity and unreliability.*
- *So a combination of wired and wireless communication.*
- *Wired cables can reach to all the main tunnels.*
- *The last mile to the sensors can be left to the wireless like capillaries.*

- Wireless
  - NFC (Near-field communication)
  - BLE (Bluetooth Low Energy)
  - Lora (Long Range, a digital wireless data communication technology)
  - Sigfox (wireless networks to connect low-power objects)
  - NBIoT (Narrowband IoT is a Low Power Wide Area Network (LPWAN) radio technology standard developed by 3GPP)
  - eMTC (LTE-M) (eMTC is a type of LTE-M network. eMTC is a low power wide area technology)
  - 5G (5th Generation is the latest generation of cellular mobile communications)

Wireless Communications

- Sensor network
  - not suitable for moving objects
  - for a small number of sensors, it is a waste
- Wi-Fi network has the drawbacks
  - short coverage, the great power consumption and the handover from cell to cell
- IEEE 802.15.4 and Bluetooth Low Energy (BLE)
  - in mobile indoor scenarios (underground mine), BLE is more energy-efficient than 802.15.4
  - The concept of a BLE broadcasting-scanning mechanism, developed by UNSW MERE to meet the requirements to obtain a small amount of data at a relatively low rate (research is ongoing).

BLE

- Broadcasting-scanning mechanism
  - Small amount of data
  - Low rate
  - Two types of devices
    - transmitters and receivers
    - sensors are transmitters to broadcast message using BLE
    - the BLE scanners are receivers which scan the message in the environment to obtain the data that the sensors send out
    - the receiver can connect to a wired cable through i.e. a router

<u>One direct application, positioning system for the underground mines.</u>

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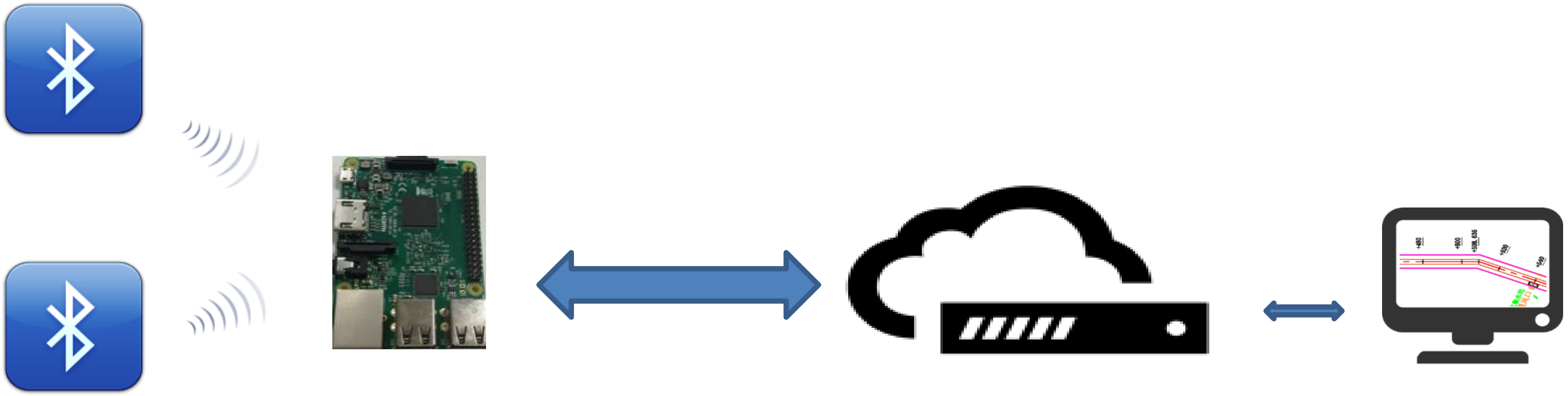
System Structure



Positioning tag

BLE scanning node

Pros and Cons

- ✓ Simplicity
- ✓ Low power consumption - (average 100µA level)
- ✓ Long range (up to 2km)
- ✓ Low cost (less than 10 USD)
- ✓ Flexible to handle many sensors

- ❖ Not suitable for a large amount of data

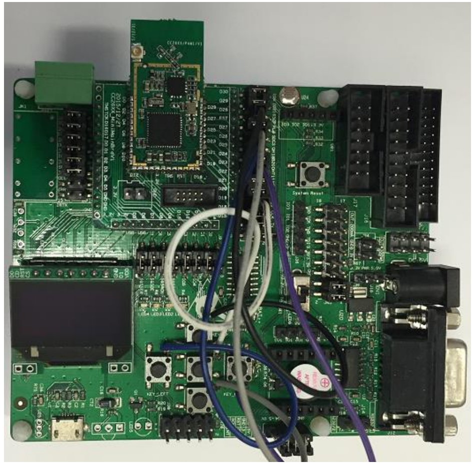
Testing Devices

- BLE transmitter
  - CC2650,
  - CC2650+CC2592
- BLE receiver + evaluation board
  - CC2650,
  - CC2650+CC2592
- RPi (built in BLE)


CC2650

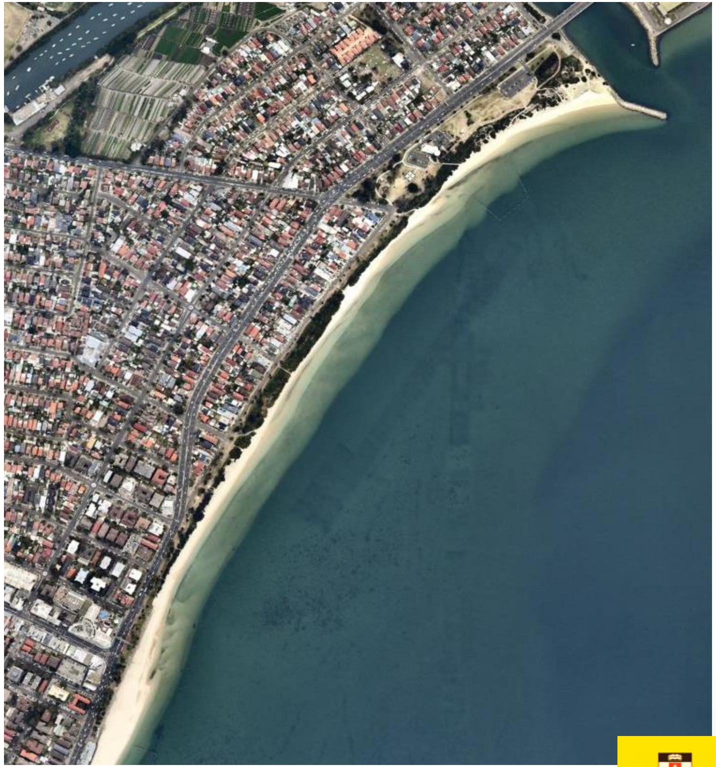

CC2650+CC2592


RPi 3B


Evaluation boards

Out Door Test

- Set up the tripod,
- Installed the BLE transmitters (broadcasting in 10hz)
- Carried the BLE receiver walked away from the tripod to test the max range that the receiver can capture the signal from the transmitter.



Brighton-Le-Sands Beach, Sydney

Results

- Transmitter CC2650+CC2592
  - At 910m, the receiver CC2650 performs better than CC2650+CC2592
  - 1900m away, at high location, can still receive 30% and the body can block the signal completely.
- Transmitter CC2650 only
  - range between the transmitter and the receiver was shorter (maximum 550m)
- Using CC2650+CC2592 as the transmitter and CC2650 as the receiver performs the best

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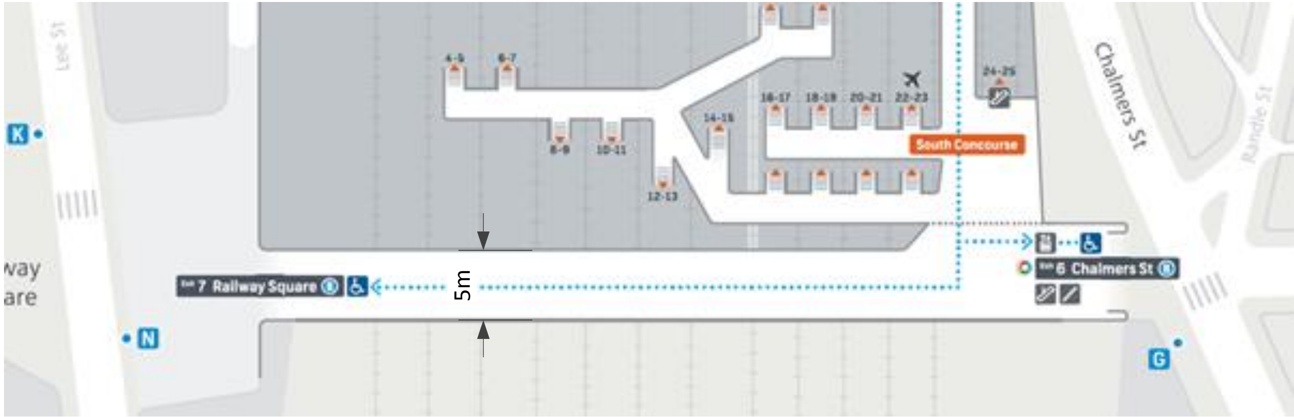
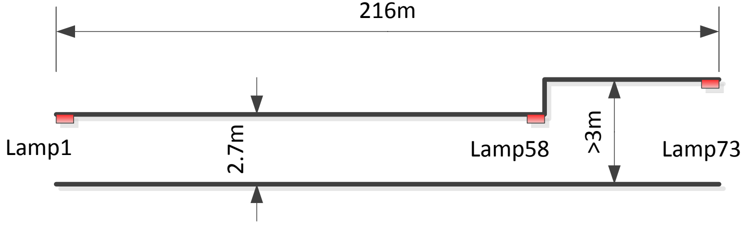
Tunnel Testbed





Sydney Central Station pedestrian tunnel map (top), Lateral view (bottom)

Testing

- Four sets of tests
  - Normal BLE transmitter, normal BLE receiver and amplified BLE receiver
  - Amplified BLE transmitter, normal BLE receiver and amplified BLE receiver
  - Amplified BLE transmitter, RPi BLE receiver
  - Normal BLE transmitter, RPi BLE receiver
- The transmitter was at a fix location, the receiver was located at 30m – 210m
- The data was broadcasted at 10Hz

Results

- Normal transmitter + normal receiver (CC2650 only, without amplifier); 120m is the limit, still over 10% receiving rate
- Amplified transmitter, normal receiver, the distance can extend to at least 210m

A Typical Application

- Underground tracking system
- Testing is undergoing

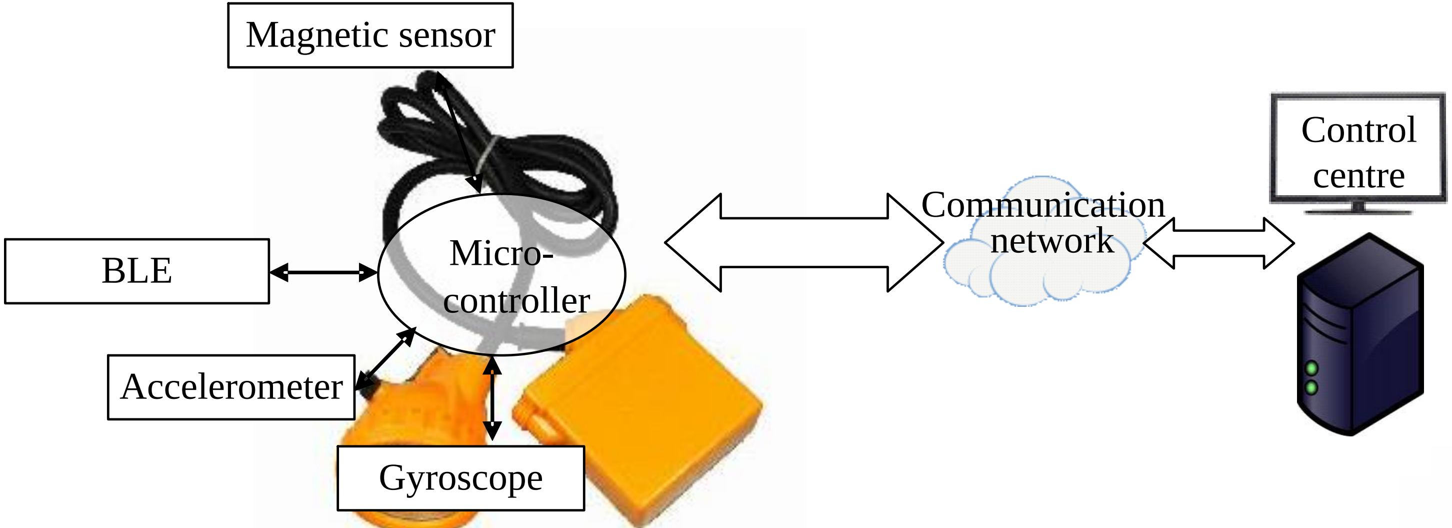
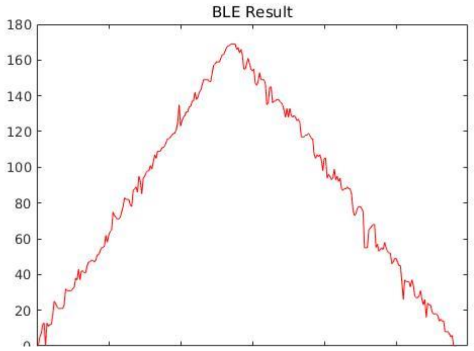
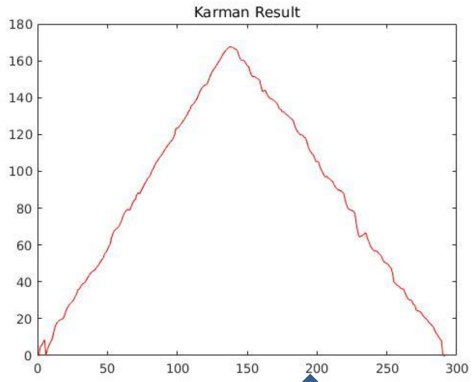


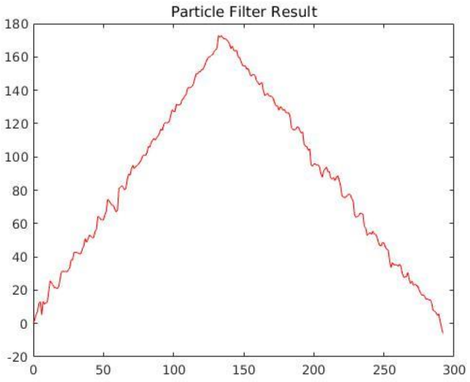
Figure 1. The structure of the proposed system (using personnel worn tag as an example)

Underground Tracking System Test

BLE Testing - Walking







BLE only

BLE + Kalman filter

BLE + particle filter

Upcoming Events