

# Elderly Medication Adherence Monitoring with the Internet of Things

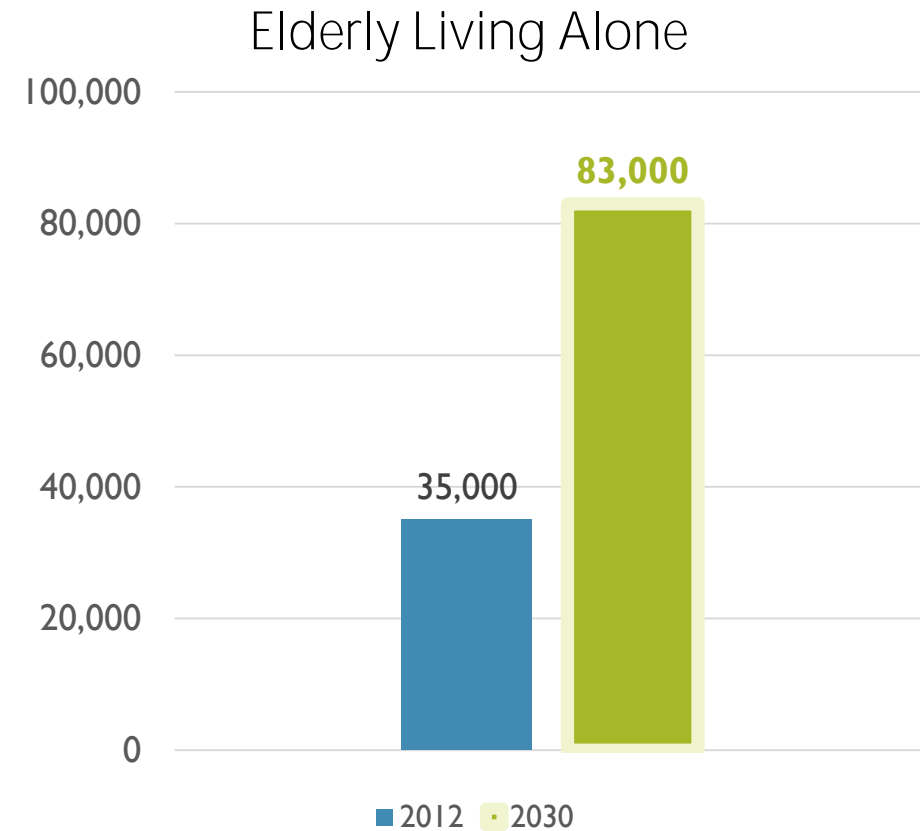
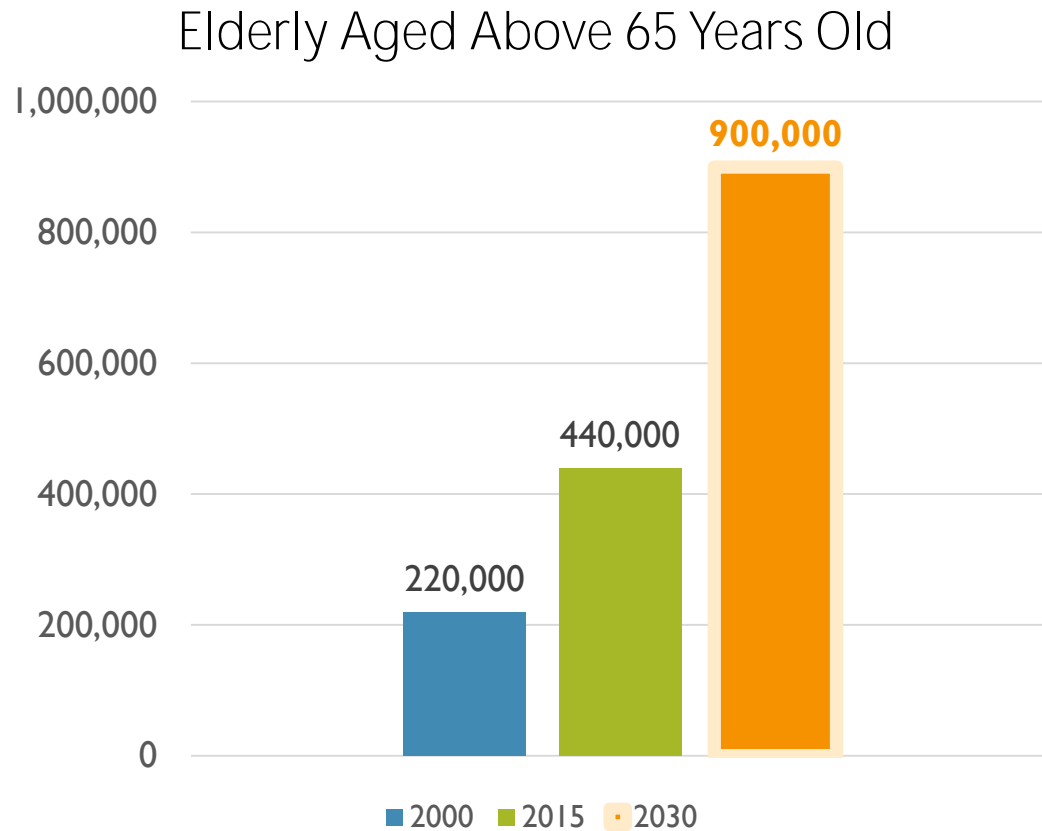
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# Singapore's Ageing Population

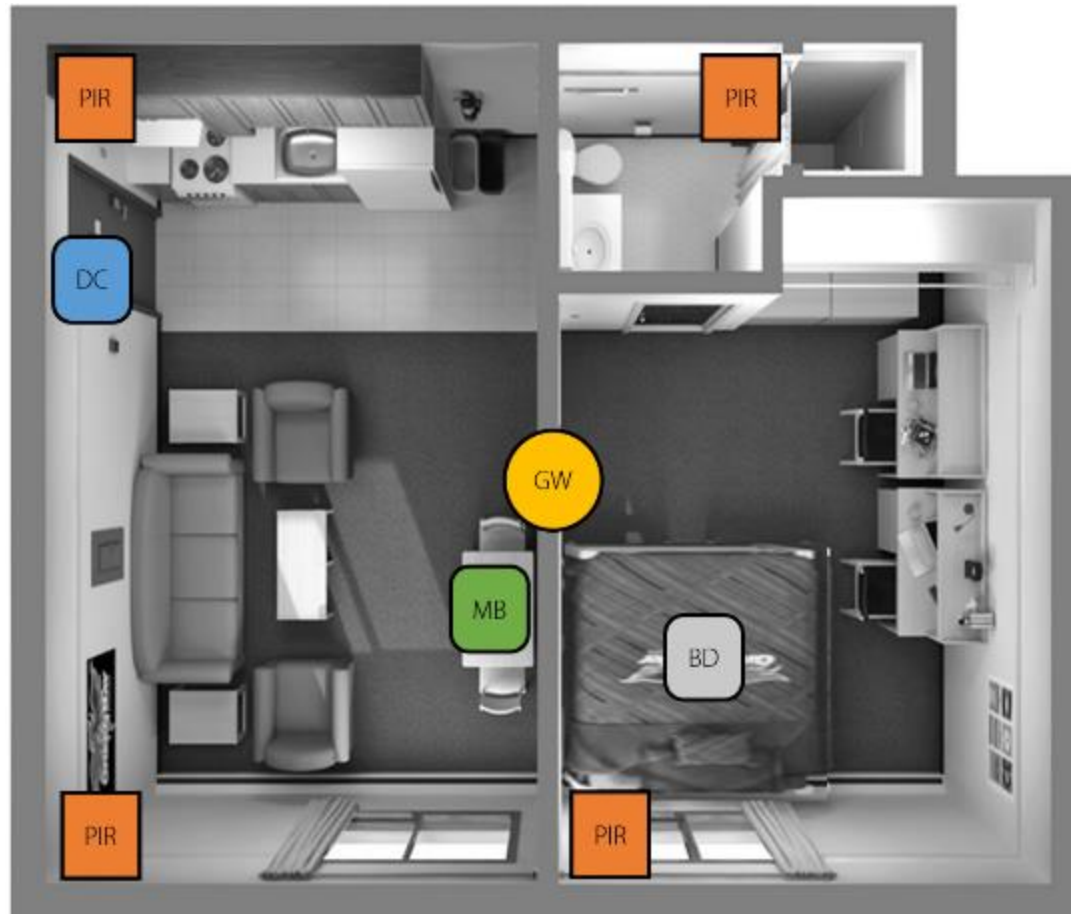


National Population And Talent Division, Singapore

# Enabling Ageing-In-Place through Technology



(e.g. sensor-enabled homes)



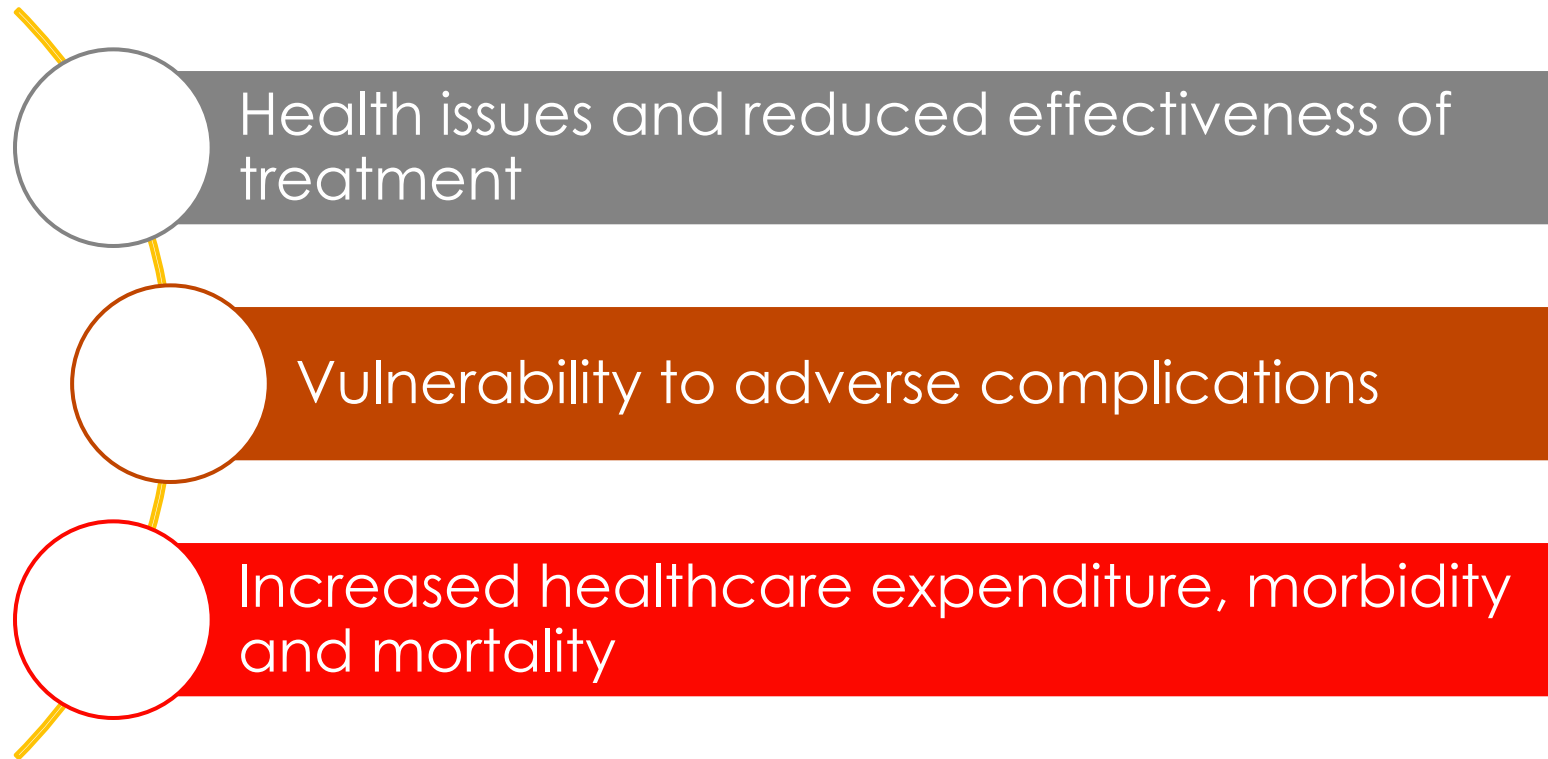
## Legend



Supported by the Singapore Ministry of National Development (MND) and National Research Foundation (NRF) under L2NIC Award No. L2NICCFP1-2013-5.

# Importance of Monitoring Medication Adherence

- Medication non-adherence leads to:



# Limitations of Existing Products

Expensive with recurring costs

Cannot be customized to **elderly's preferences and consumption habits**

Non-interoperable with other sensing devices

Non-integrated with personalized care model

Existing medication habits of elderly



# A Solution for *Inferring* Medication Adherence

- Medication box that can be personalized **according to elderly's current medication habits**
- Unobtrusive and non-intrusive
- Allows real-time monitoring, for reactive intervention by caregivers
- Allows longitudinal monitoring, for pre-emptive intervention by caregivers



Currently, the only way to accurately detect medication adherence is through image-based solutions or ingestible medicine.

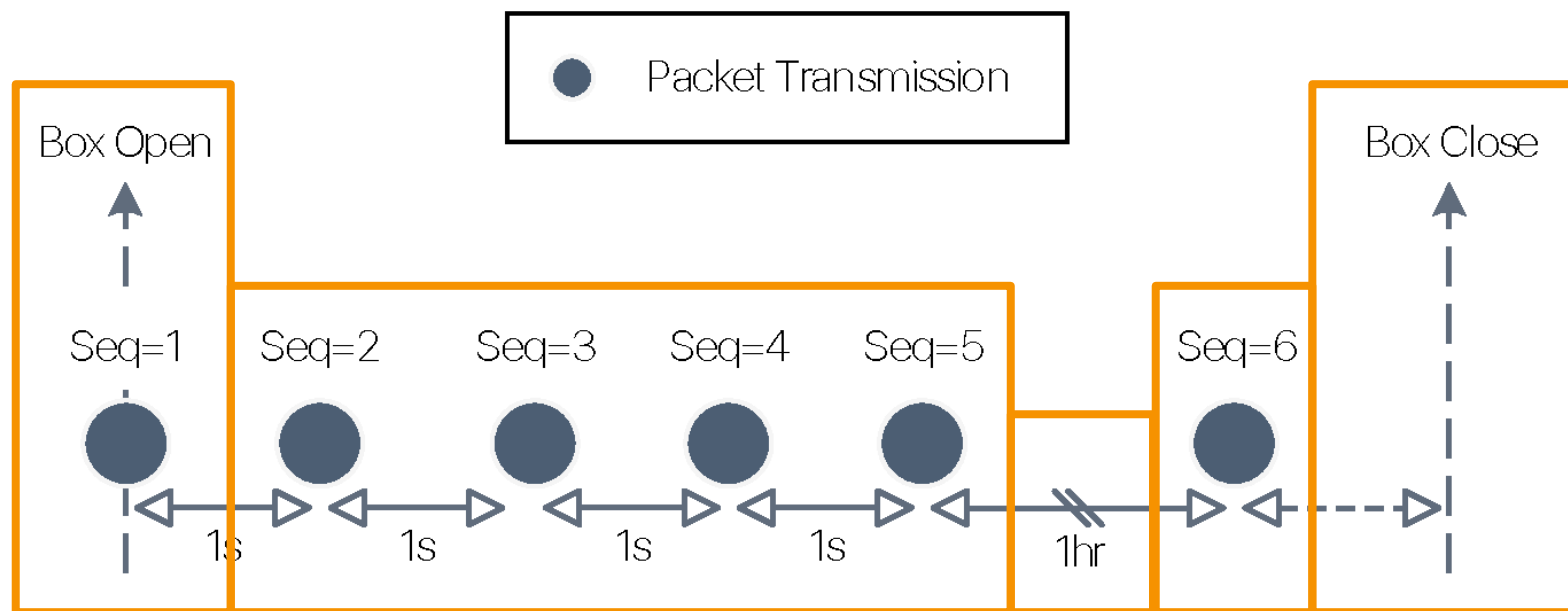


# Medication Box Prototype



(Normally Closed) Reed Switch  
Arduino Fio (microcontroller)  
Xbee radio (IEEE 802.15.4)  
LiPo battery

# Packet Transmission Schedule in MedBox Sensor



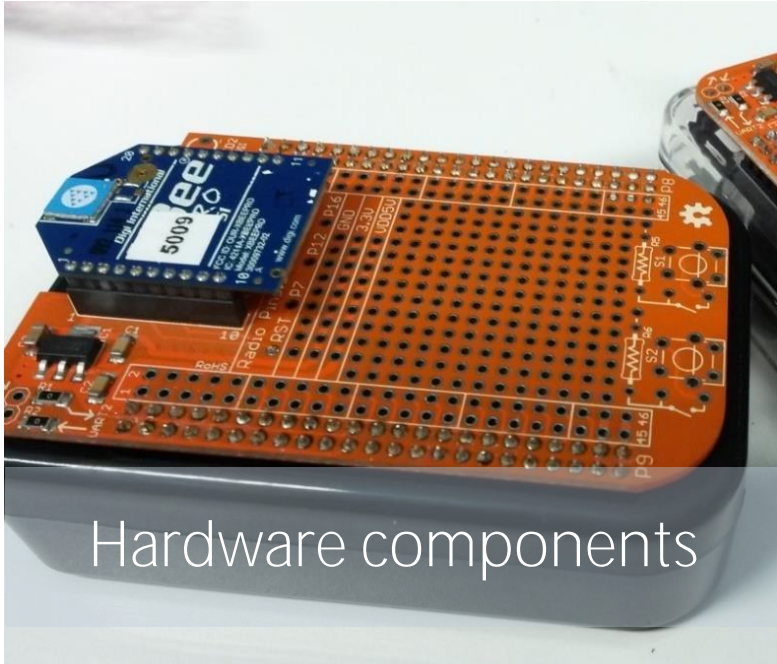
Reed switch breaks contact with magnet, board is powered on

Multiple pkt txn for redundancy and reliability

Sleep period to conserve energy that board is not closed  
 Continued tx until reed switch makes contact with magnet, board is powered off



# Medication Box Gateway



Hardware components

Beaglebone Black  
Xbee radio (IEEE 802.15.4)  
3G dongle + SIM card

Receive pkts  
from sensor(s)

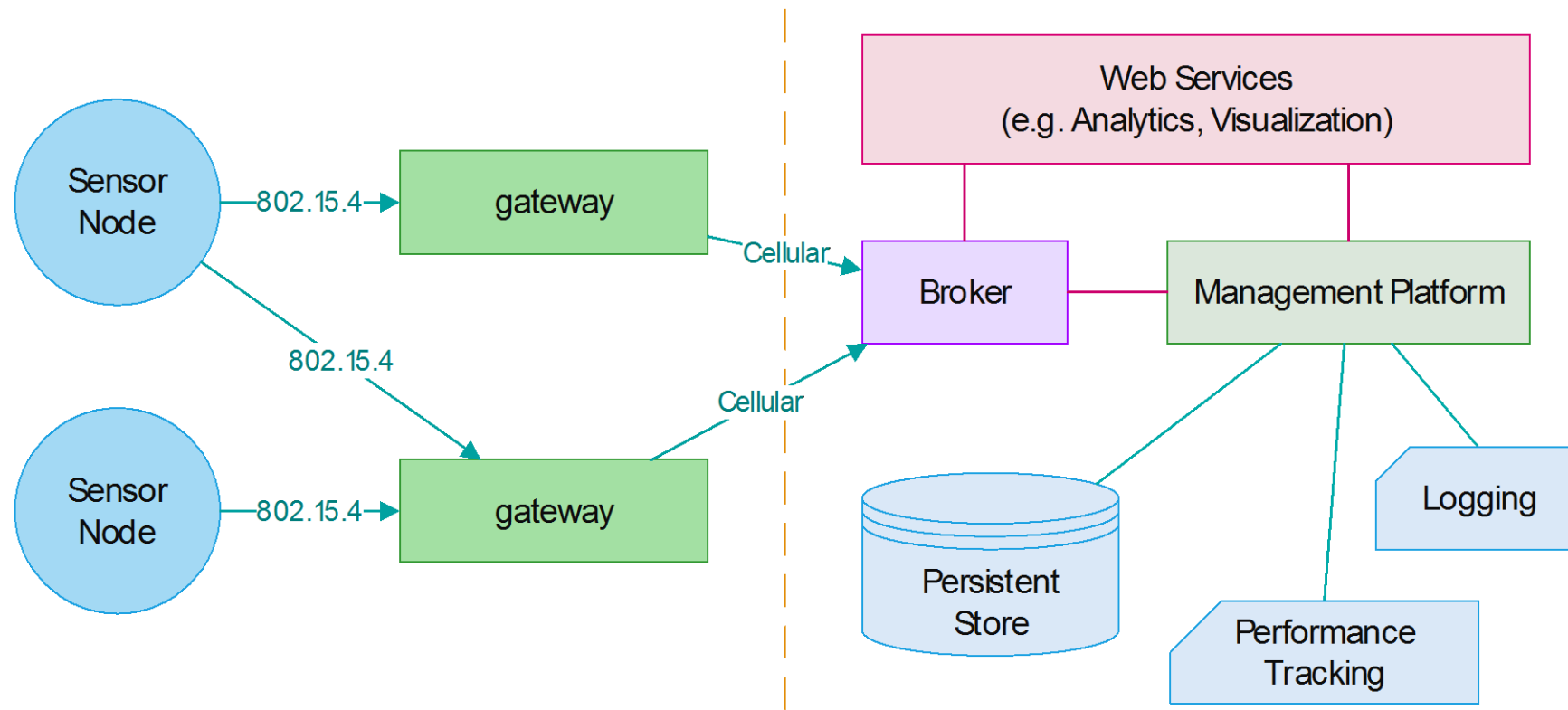


Publish data to  
backend  
through MQTT

# Monitoring and Analysis

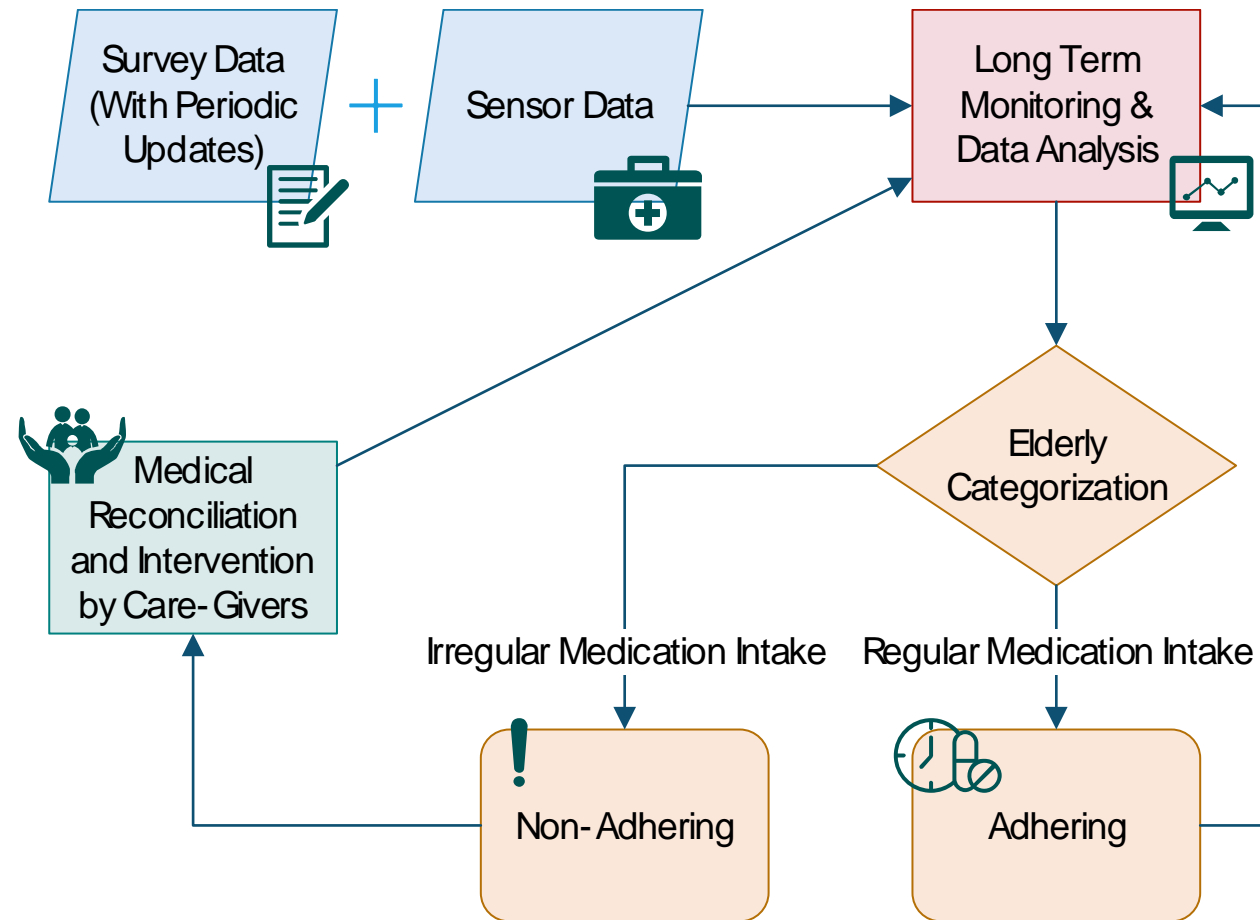
- Density-Based Spatial Clustering of Applications with Noise (DBSCAN) to cluster medication intake timings
  - Distance function :: cyclic difference between any two medication intake timings
  - $\epsilon = 1$  hr :: maximum distance between two medication intake timings that can be considered to be in the same cluster
  - *MinPts* = 5 :: minimum number of points in cluster ( $\epsilon$ -neighborhood)
- Descriptive statistics to deduce regularity of inferred medication intake frequency

# System Architecture

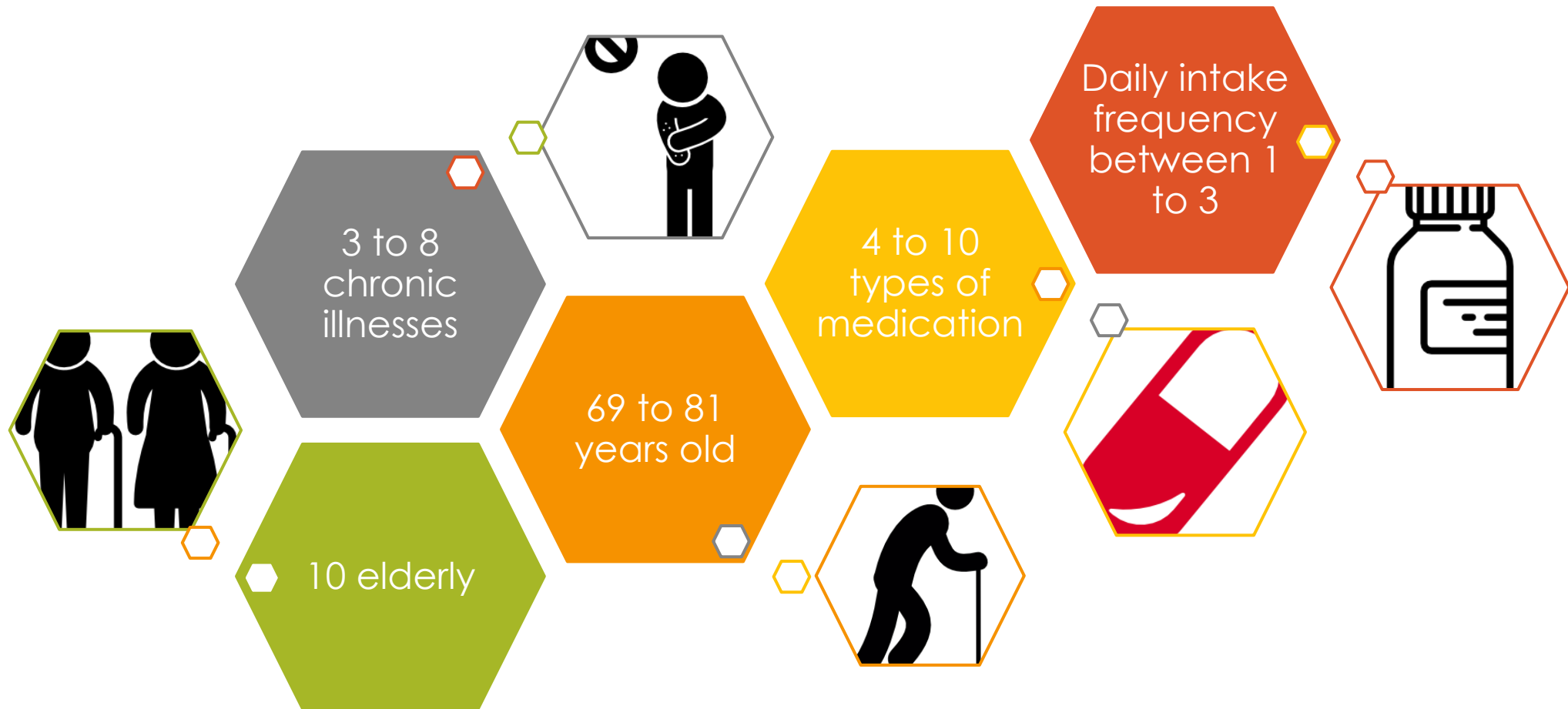


\*Anycast routing is used for reliability and robustness, as well as to decrease cost.

# Elderly Care Model

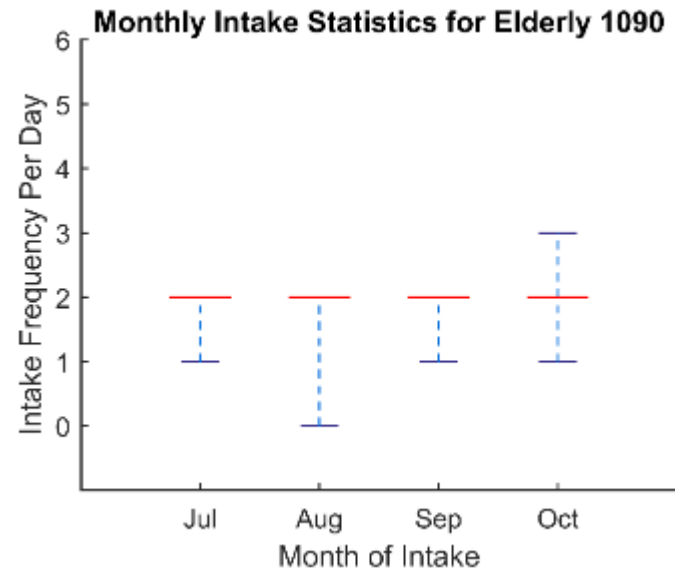
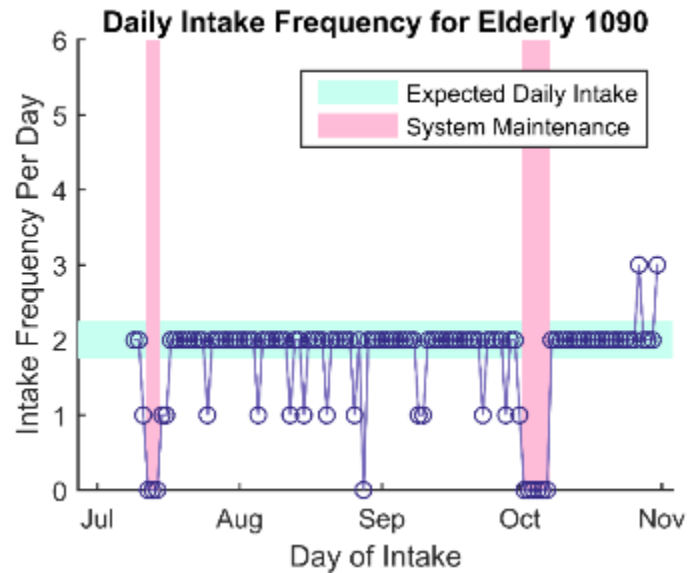


# Participant Profile



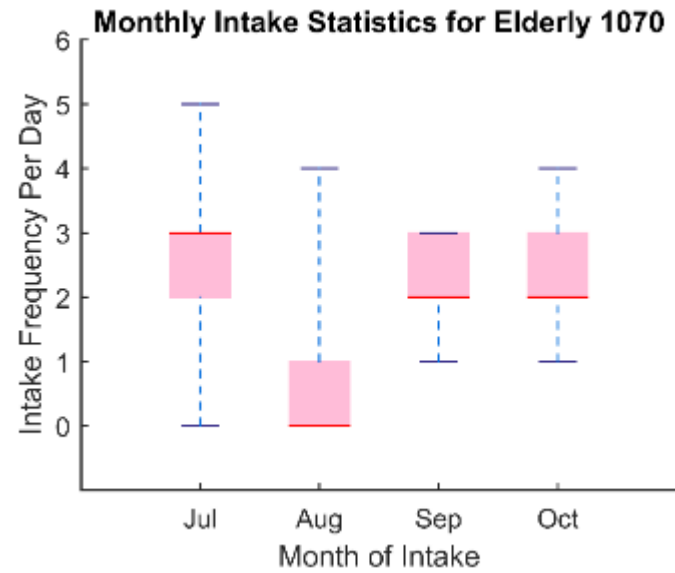
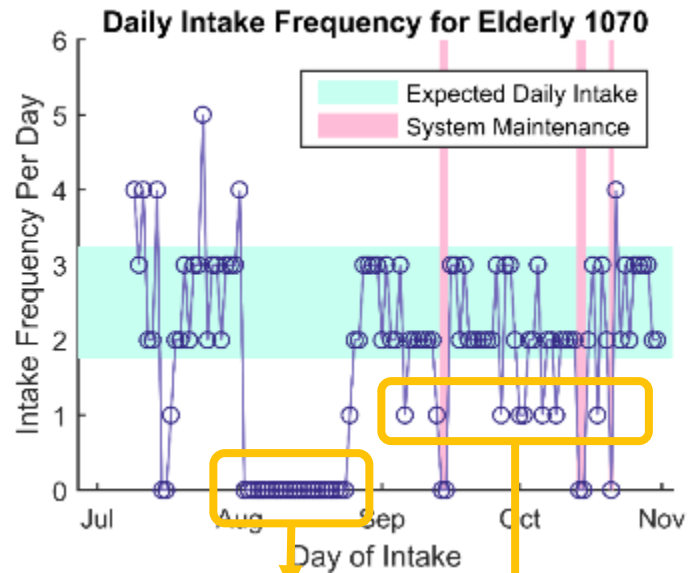
# Inferred Medication Intake Frequency

## Elderly 1090 – the “Role Model”



# Inferred Medication Intake Frequency

## Elderly 1070 – the “Frequent Flyer”



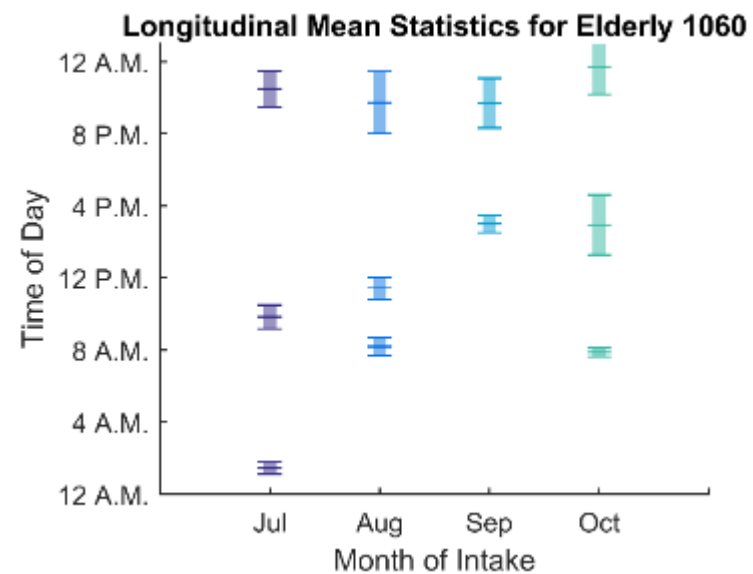
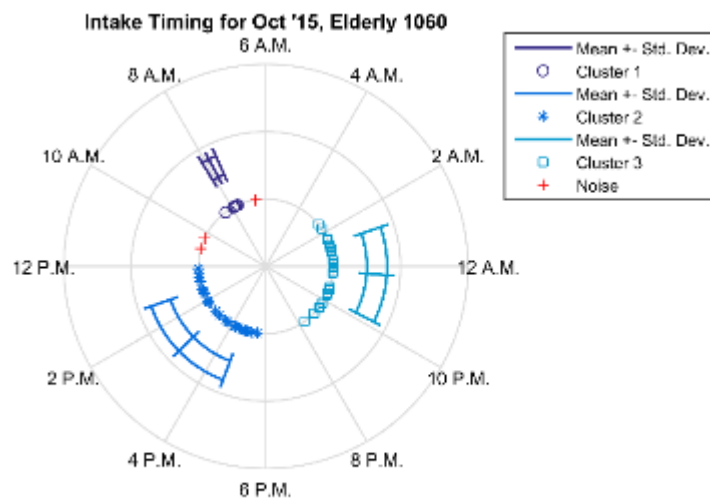
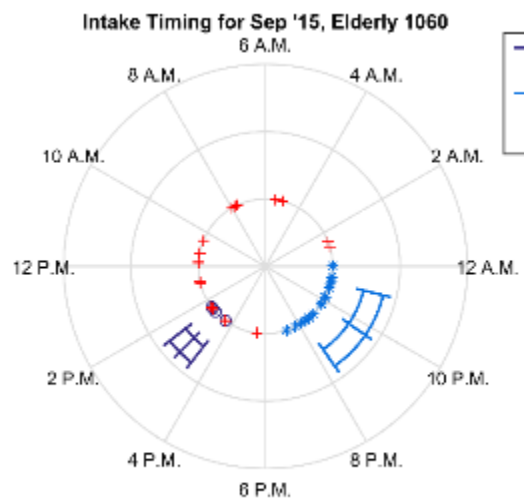
hospitalization

outdoor activities on Sundays



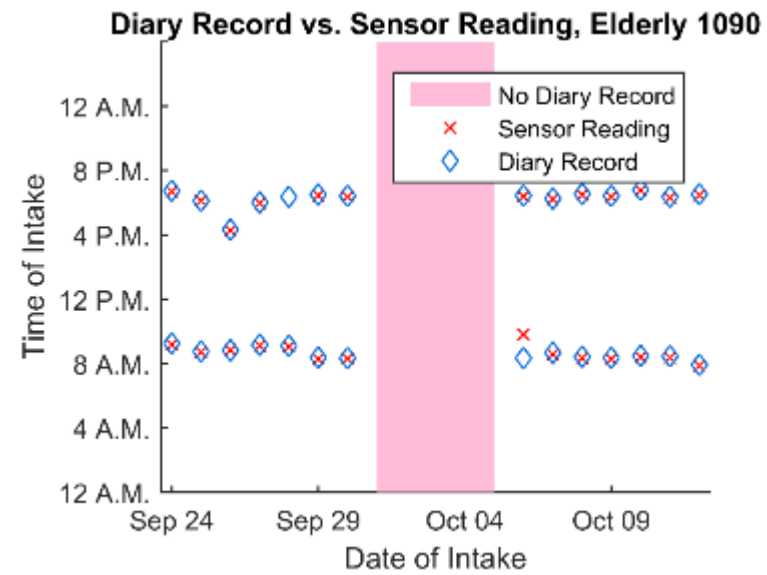
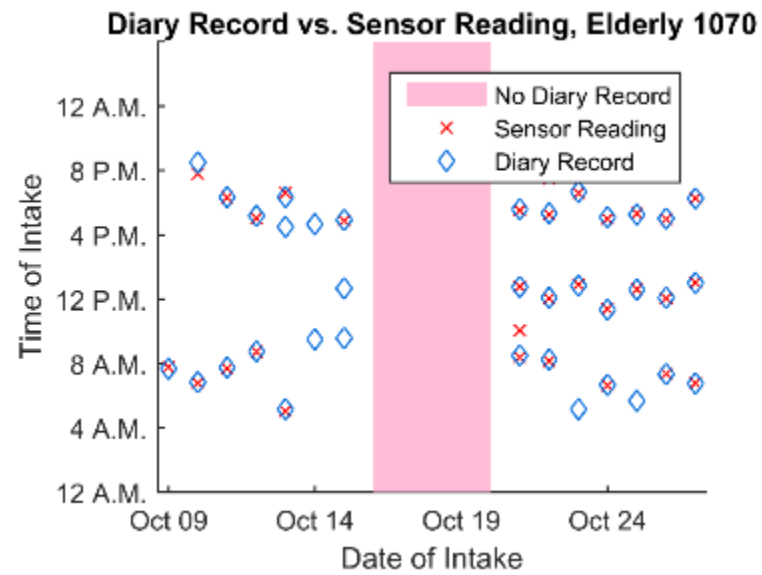
# Medication Intake Timings

## Elderly 1060



# Ground Truth Evaluation

## Two-Week Medication Diary



# Discussion and Insights

- Elderly are concerned about electrical consumption of mains-powered gateway
- Elderly with active lifestyles tend to upset daily medication routine
- Only medication consumption can be inferred
  - Dosage and type of medication cannot be monitored



# What's Next?

- Increase duration and scale of study to derive both longitudinal and transversal insights in medication adherence
- Work more closely with caregivers and medical professionals to better provide holistic care model

# Thoughts?

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