# Measuring Building Occupancy through ICT Data Streams

ECEEE 2017 Summer Study

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EPSRC
Engineering and Physical Sciences Research Council

# Future-Proofing Facilities Management

Sainsbury's

Estates Facilities
Imperial College
London

**Office**
**Imperial Estates**

- Imperial College administrative hub
- Centralised heating, cooling, and ventilation systems
- Uses thermal energy from combined heat and power system and campus heating loop

- Staff access tracked by ID card at 8 building entrances
- Digital meeting schedules for conference rooms

**Supermarket**
**Sainsbury's**


- Large standard floor plan supermarket
- Biomass boiler serving 3 air handlers
- Over 50 refrigeration cabinets using $CO_2$ refrigerant
- No additional space cooling required

LAING O'ROURKE

Honeywell | TREND

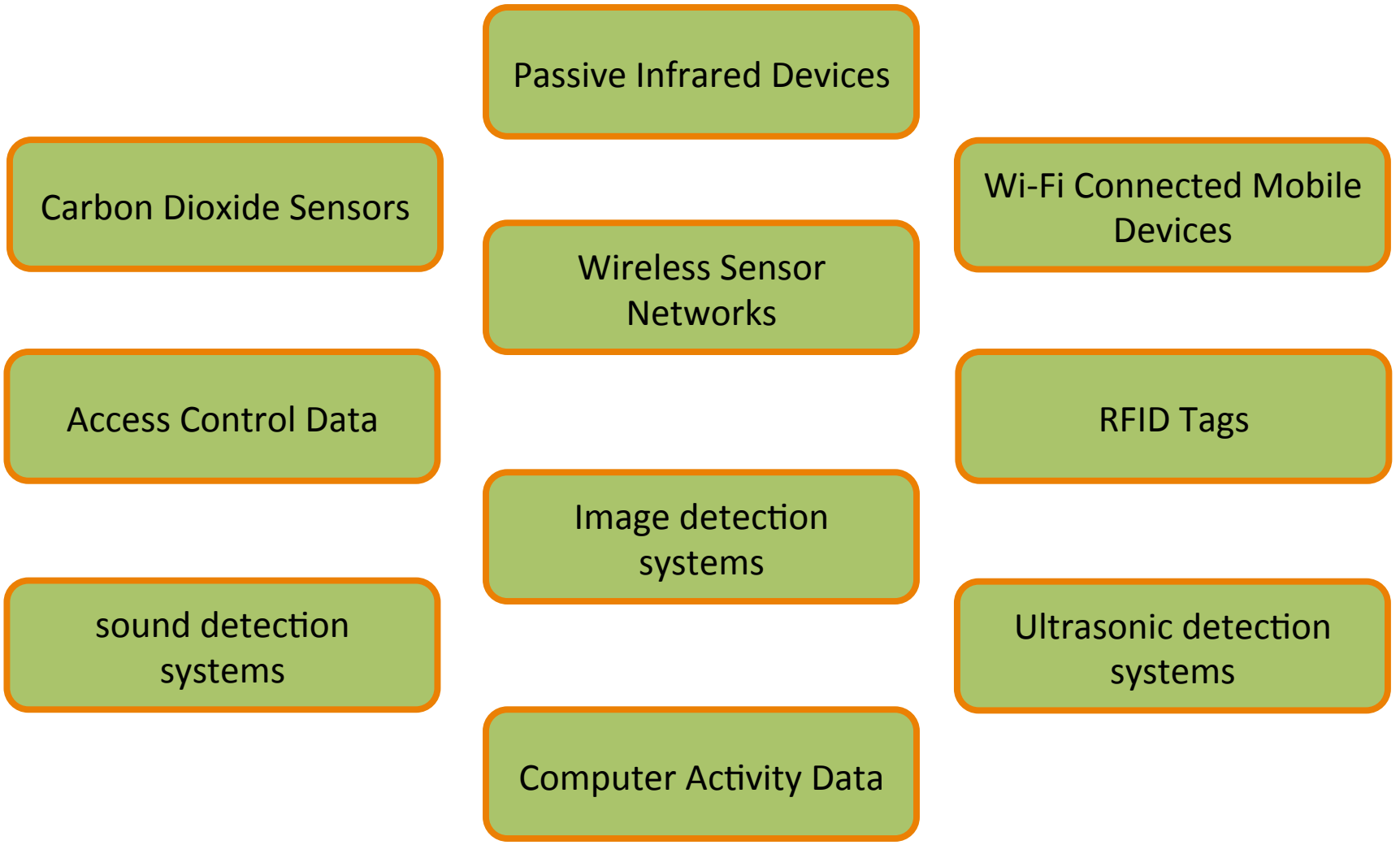
# Occupancy & Energy Efficiency

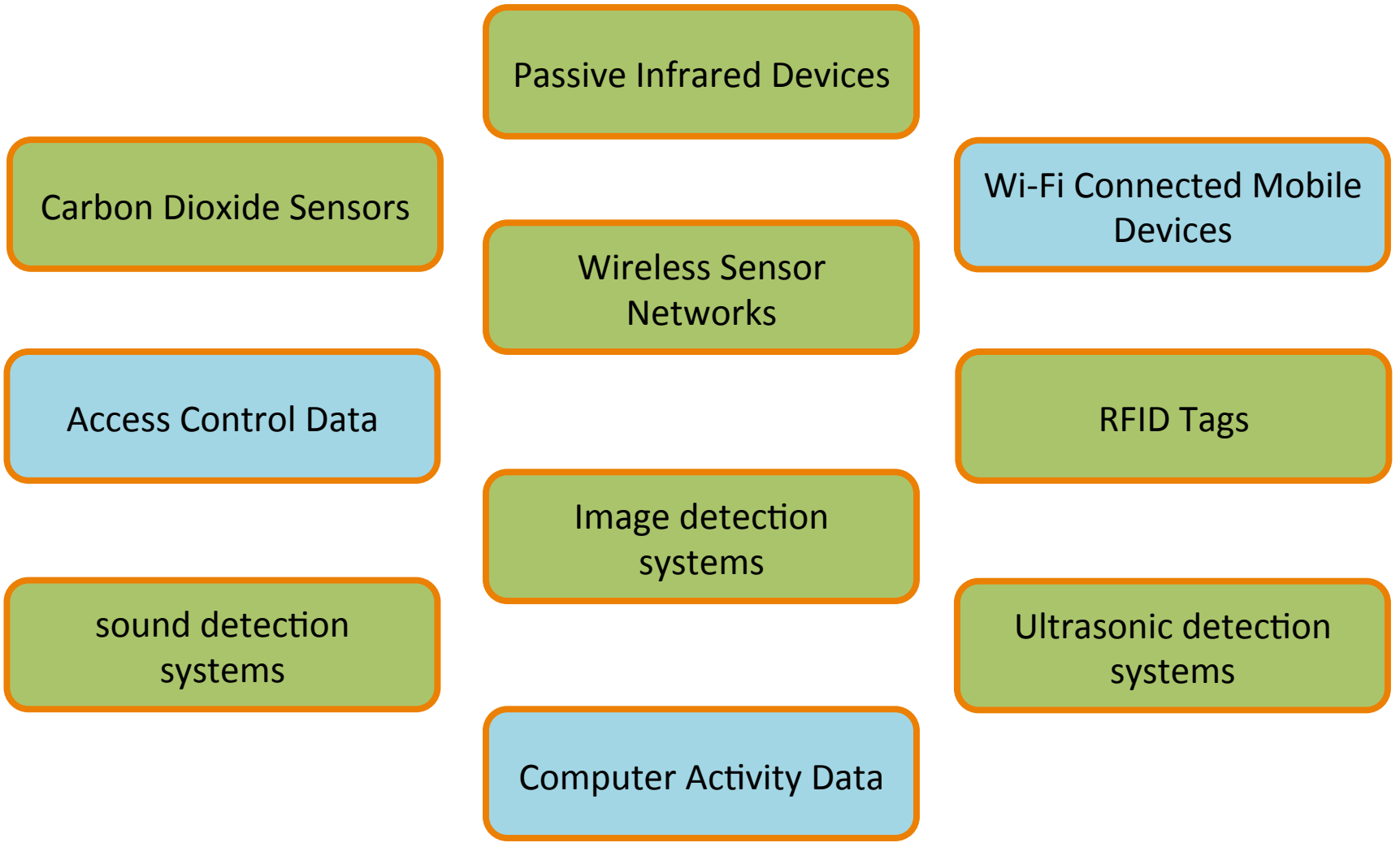
**HVAC Operation**

- Define Occupied/ Unoccupied Status
- Sensing for Demand Controlled Ventilation
- Prediction of Internal Loads for MPC strategies

**Estimated Savings**

| Residential | | Commercial | |
|---|---|---|---|
| 28% | Motion sensors + door switch with Deep Set backs | 23% | Unoccupied Setbacks + Variable air flow |
| 11% | Nest (Motion Sensor) for setbacks during unoccupied periods | 14% | Camera Network for Variable Air Flow |


Passive Infrared Devices
Carbon Dioxide Sensors
Wi-Fi Connected Mobile Devices
Wireless Sensor Networks
Access Control Data
RFID Tags
Image detection systems
sound detection systems
Ultrasonic detection systems
Computer Activity Data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Computer Activity Data

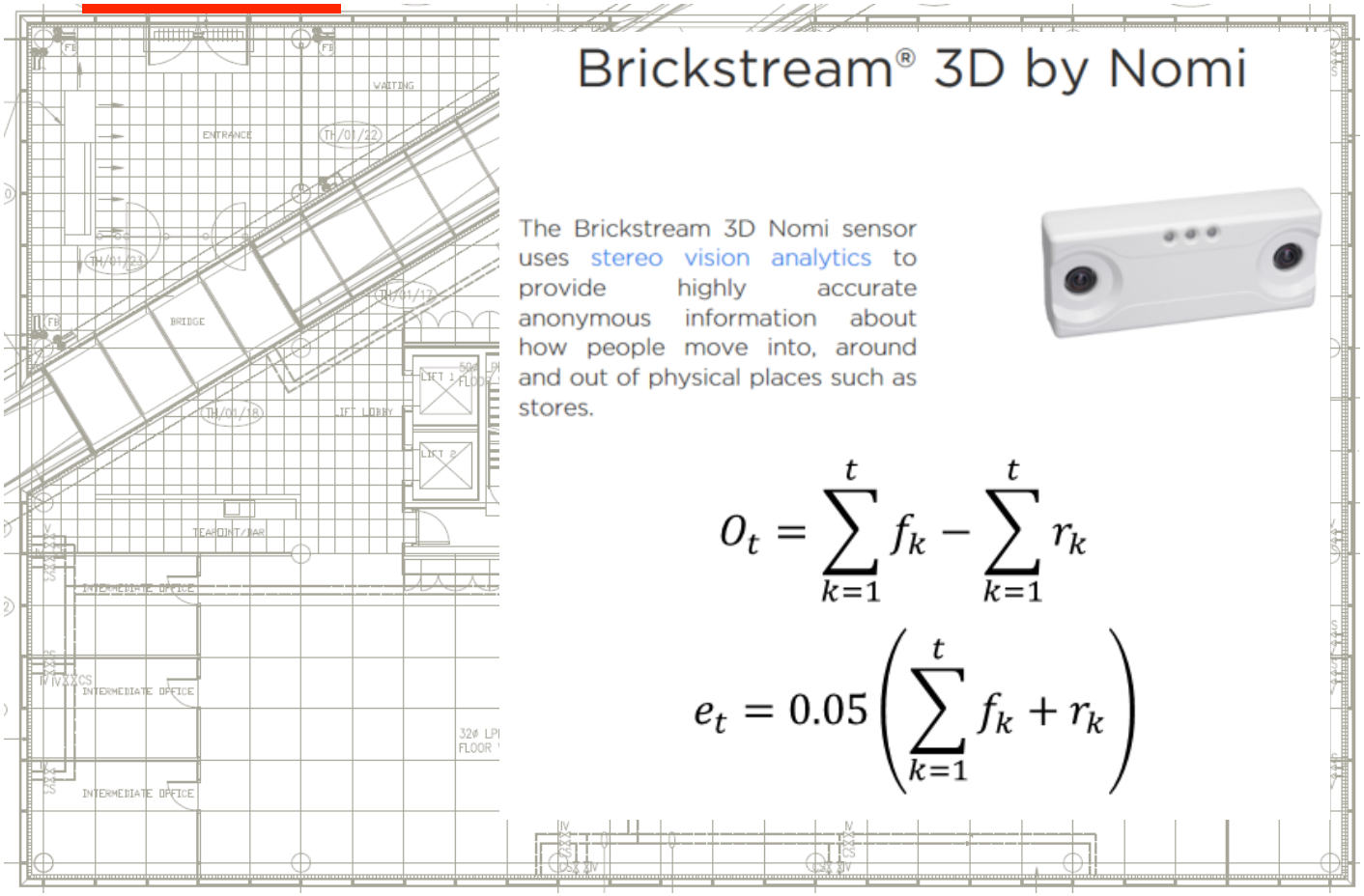
# How well do ICT data sets *measure* occupancy?

Access Control Data

Computer Activity Data

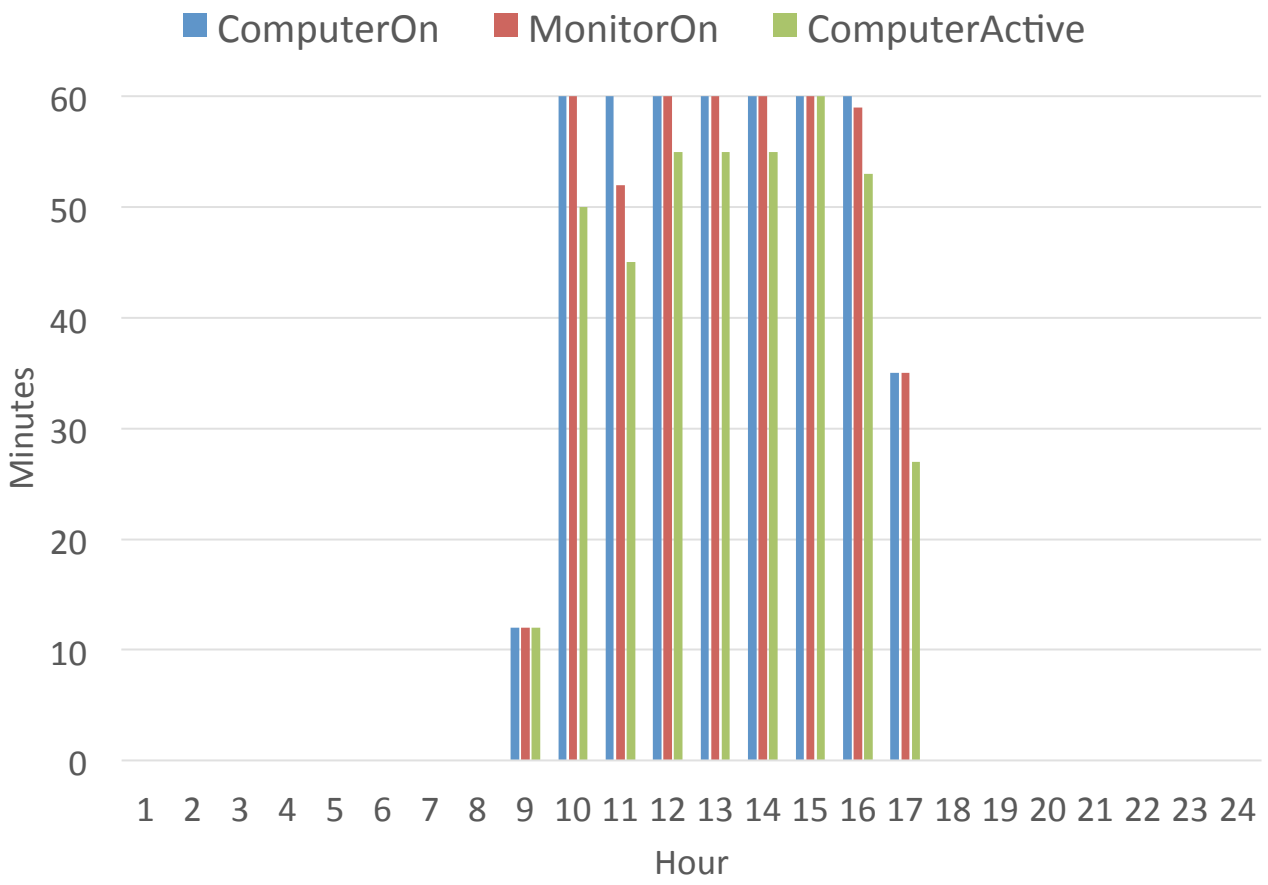
Wi-Fi Connected Mobile Devices

# Commercially Available Occupancy Counters



# Computer Activity

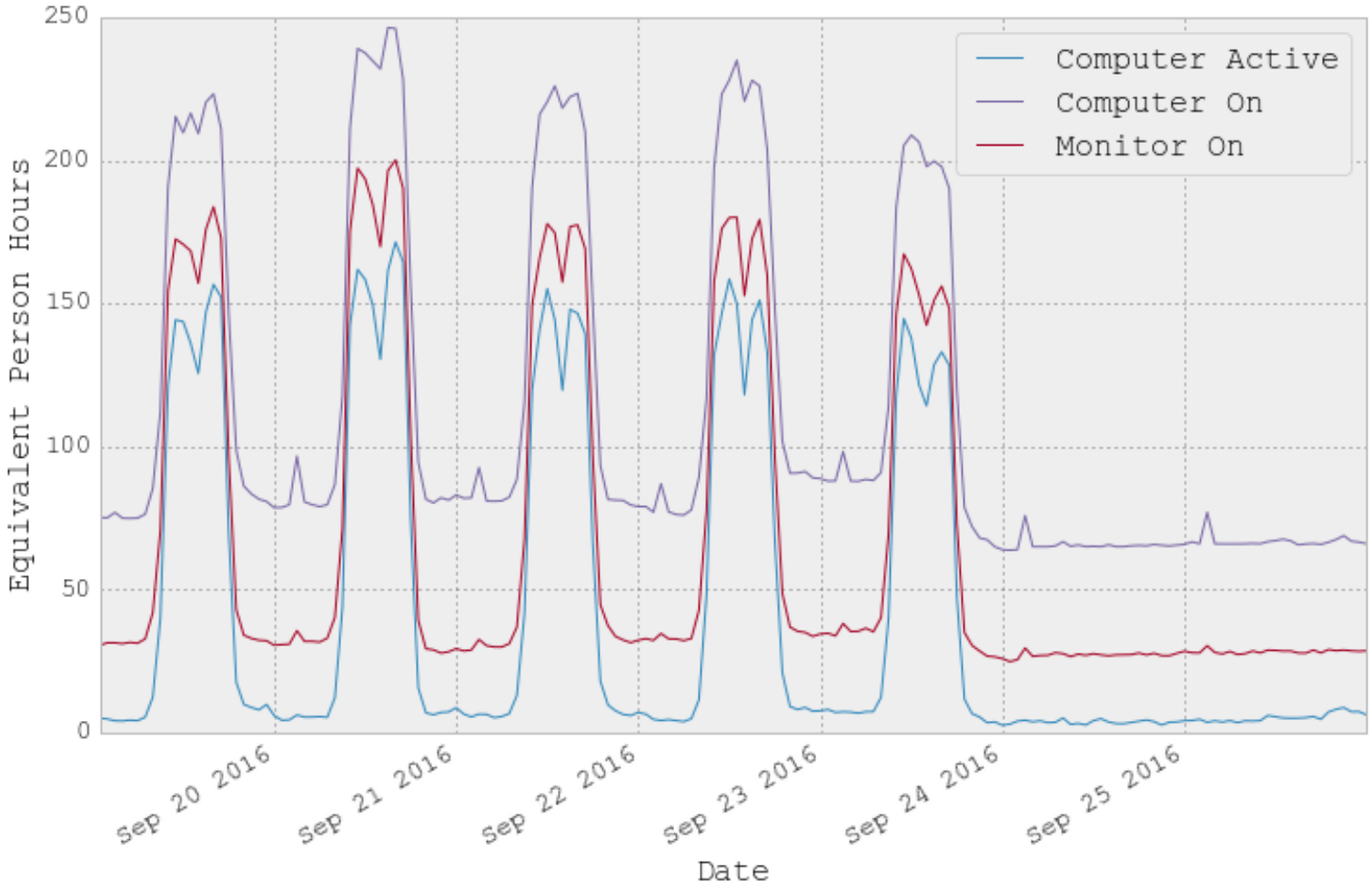
# Activity Data Metric



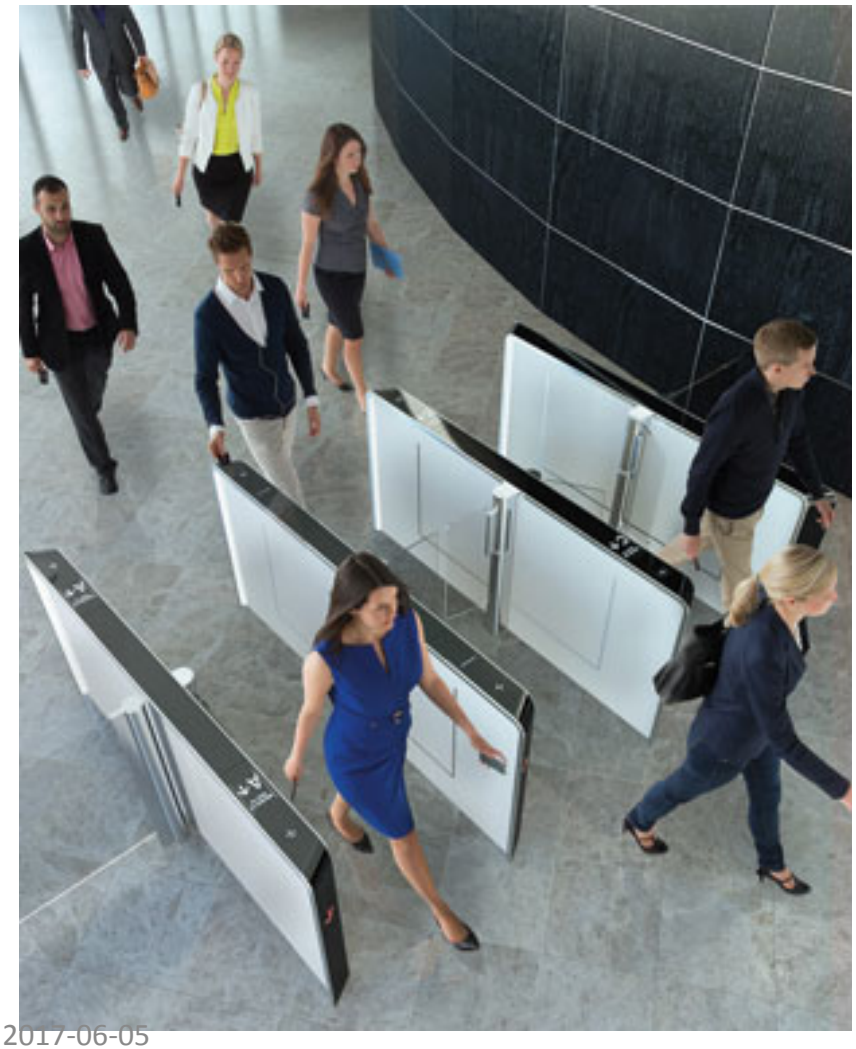

## Equivalent Person Hours

$$O_t = \sum_{n=1}^{N} \frac{m_{n,t}}{60}$$

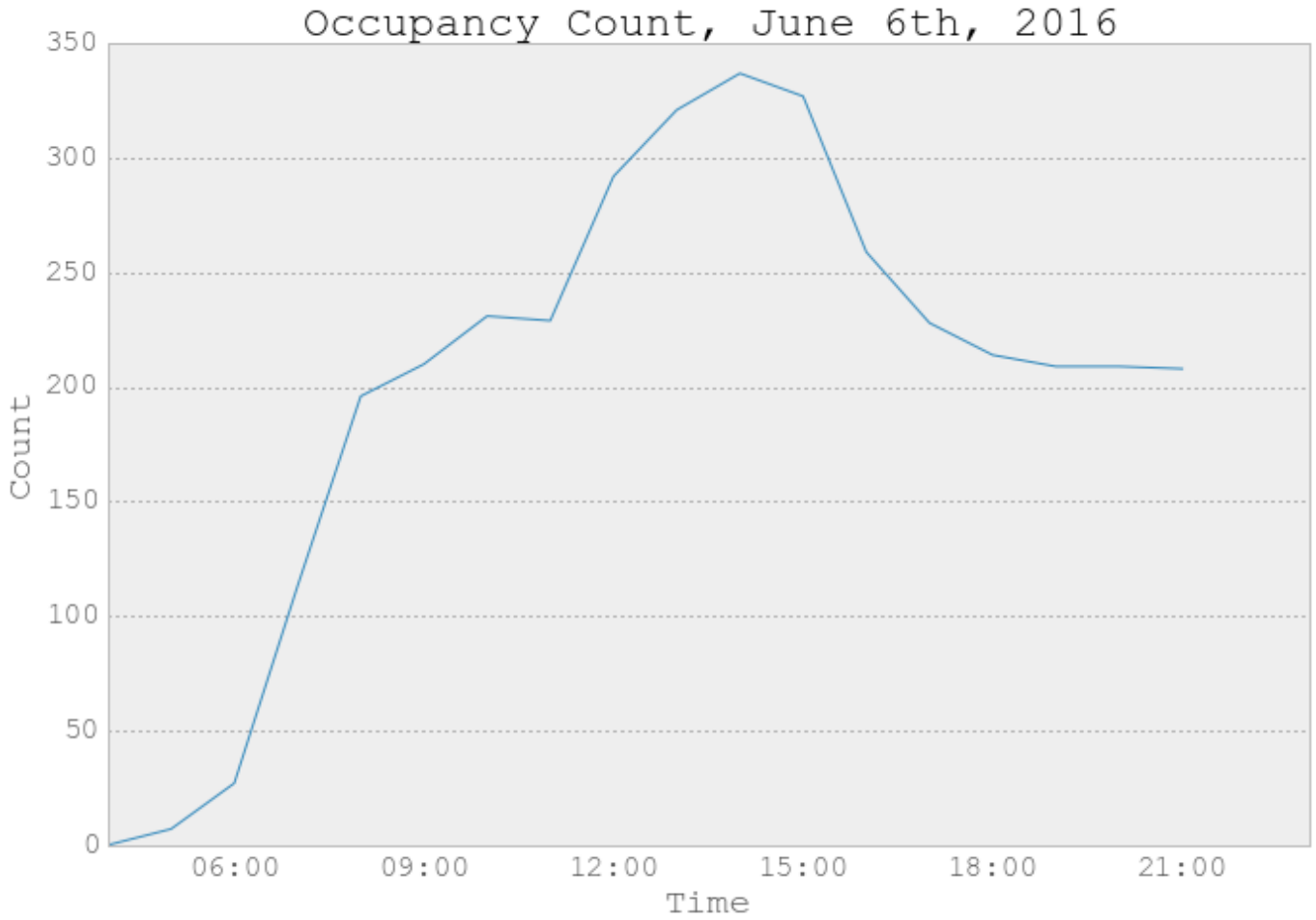
# Activity Data Metric



# Access Control Points



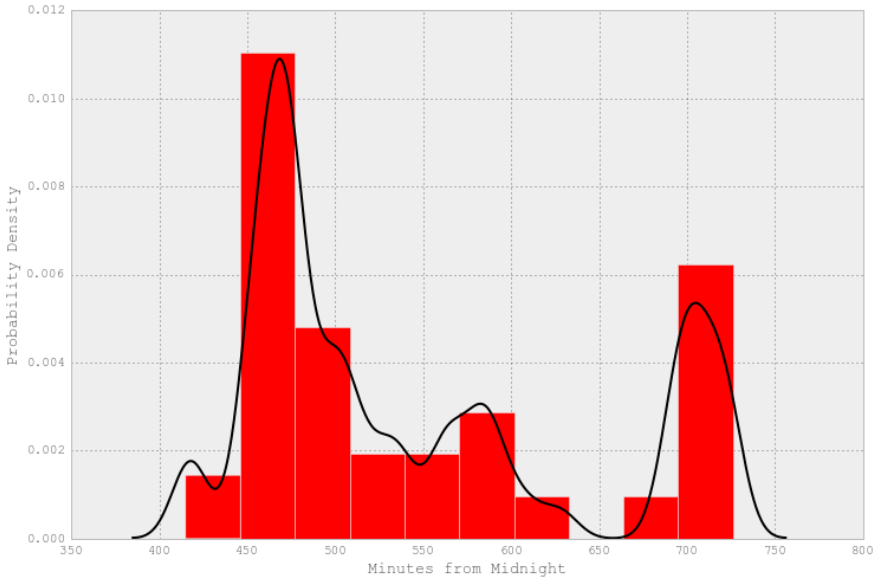
# Access Control: Missing Data



# Access Control Data

```
In [22]: ind['2016-10-03']
Out[22]:
                     IN_OUT      floor          building
EVENT_TIME_UTC
2016-10-03 12:15:10    OUT  4th Floor  Faculty Building
2016-10-03 12:26:37     IN  4th Floor  Faculty Building
2016-10-03 13:44:12    OUT  4th Floor  Faculty Building
2016-10-03 14:09:37     IN  4th Floor  Faculty Building
2016-10-03 16:33:07    OUT  4th Floor  Faculty Building
```

```
In [67]: ind['2016-10-03']
Out[67]:
                     IN_OUT          building      floor
2016-10-03 07:51:00     IN  Faculty Building  4th Floor
2016-10-03 12:15:10    OUT  Faculty Building  4th Floor
2016-10-03 12:26:37     IN  Faculty Building  4th Floor
2016-10-03 13:44:12    OUT  Faculty Building  4th Floor
2016-10-03 14:09:37     IN  Faculty Building  4th Floor
2016-10-03 16:33:07    OUT  Faculty Building  4th Floor
```

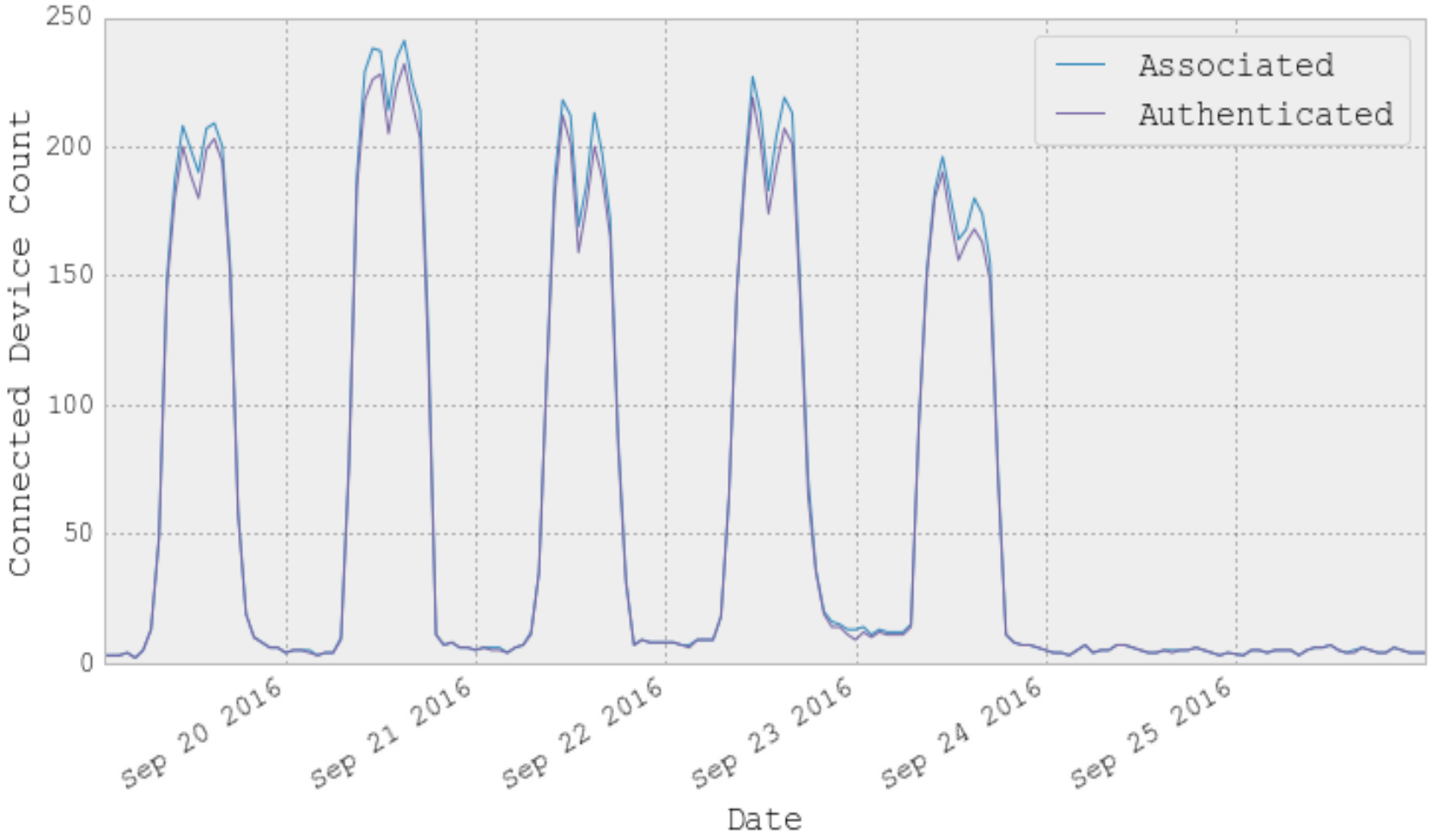



## Kernel Density Estimation

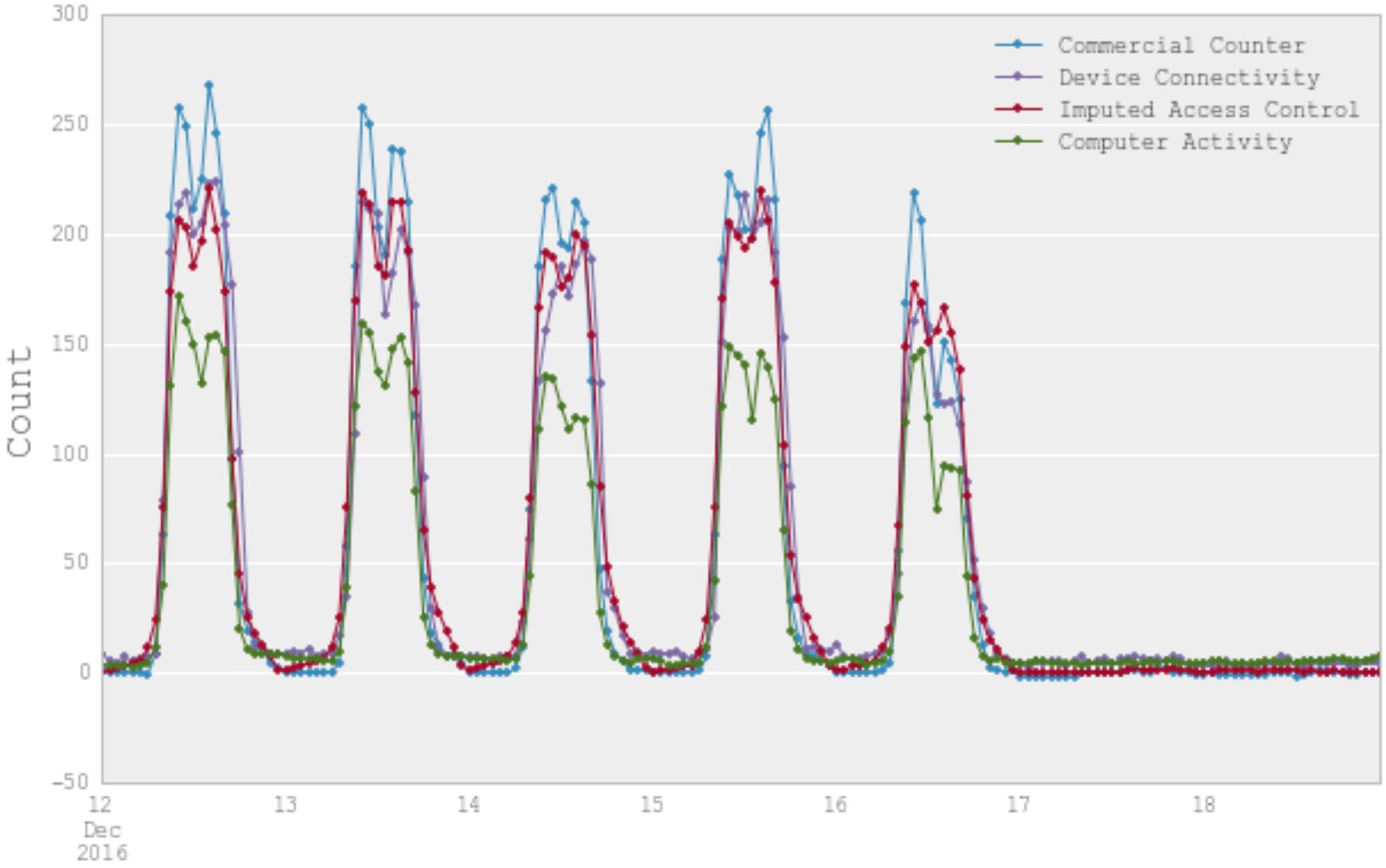
**Data:** Set of Historical Entry (Exit) times within time gap
**Kernel:** Gaussian
**Bandwidth:** Normal Reference

# Connected Mobile Devices

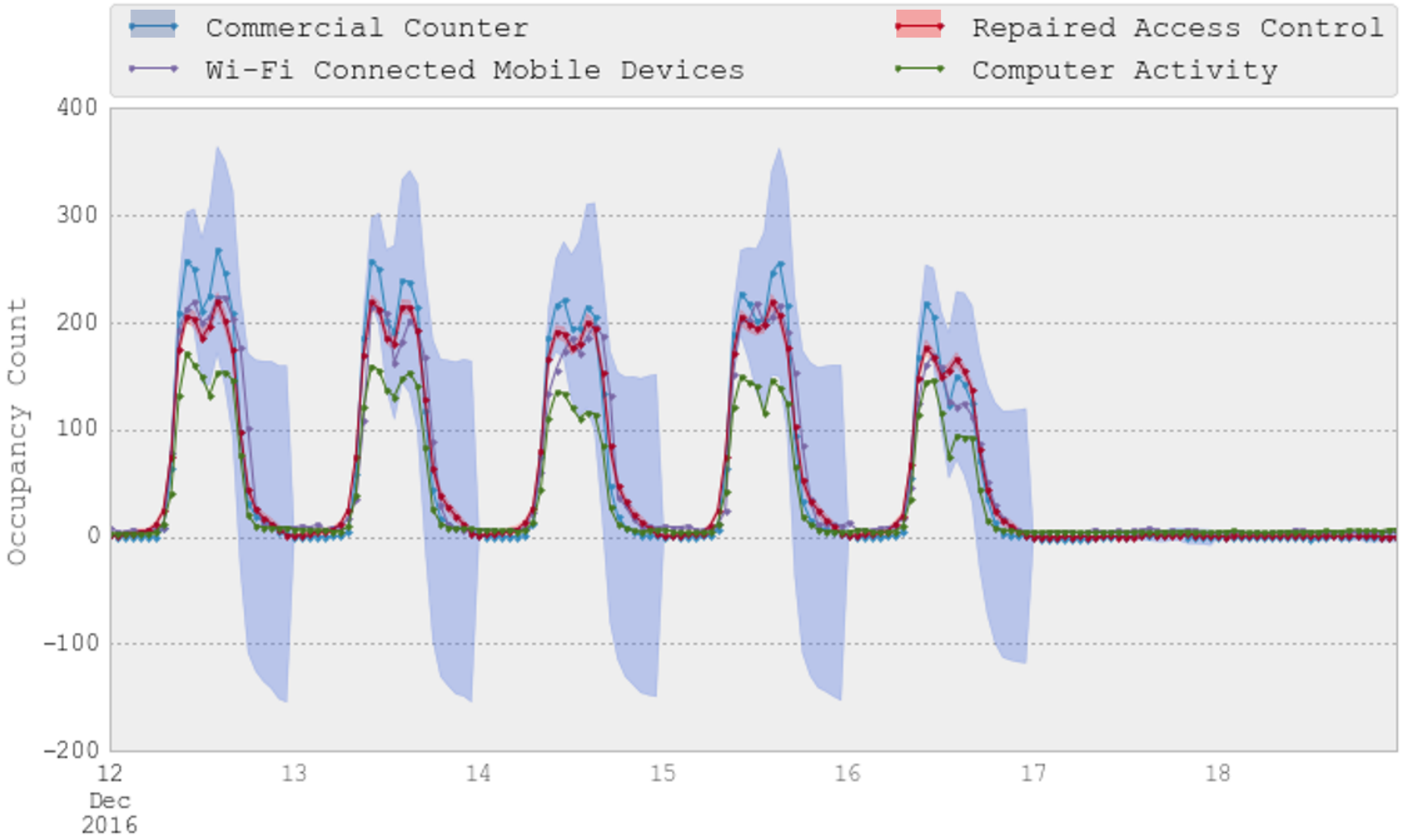
# Device Network Connectivity



# Results & Comparisons



# Results & Comparisons



# Conclusions

- High foot fall leads to large accumulative error for the commercial counters
- **Wi-Fi Connected Mobile Devices** and **Repaired Access Control Data** consistently report values within the accuracy of the commercial counters
- **Computer Activity** data consistently underestimates occupancy

# New Insights Since Publication

- Data has been collected for 18 Weeks
- Adjusted ICT-derived Occupancy Values
  - Each ICT data set is co-integrated with the measured occupancy values
  - Occupancy estimates from all 3 data sets within 20% of measured values above 10% occupancy threshold
  - Factors can be estimated accurately with only 24 hours of monitoring

# Thank you!

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