DEVELOPMENT OF AN INFORMATION MANAGEMENT FRAMEWORK FOR SMART BUILDINGS IN SINGAPORE USING NEXT GENERATION SERVICES INTERFACE: LINKED DATA (NGSI-LD)

INDUSTRIAL SYSTEM ENGINEERING AND MANAGEMENT

GROUP 12 : LOKE HONG YIT MATTHEW, SIM ZHI KAI, ZHAO XIAOYU JESSIE, TEO WEI REN

NUS DEPARTMENT SUPERVISOR: PROFESSOR AARON CHIA

SMART NATION AND DIGITAL GOVERNMENT GROUP SUPERVISOR: DR ONG ENG HWEE

IE3100R SYSTEM DESIGN PROJECT

Background

The Smart Nation and Digital Government Office (SNDGO), under the Prime Minister's Office (PMO), plans and prioritizes key Smart Nation projects and drives the digital transformation of our Government.

Project Objective

To focus on **utilizing information models in smart buildings** with the aim to demonstrate the benefits of these models by **establishing a Proof-of-Concept**, **designing an NGSI-LD-based informational model**, and **evaluating it against other industrial standards** to identify advantages and areas for improvement.

Methodology

Analyze NGSI-LD model using HVAC Case Study → **Run simulation of using Information model** using O2despy python package → **Compare NGSI-LD with Brick Model** using HVAC Case Study → **Evaluate the better model** using user's objectives and system characteristics

NGSI-LD and key properties: Entities, Relationships, Properties/Values

Entities

```
Floors
{
  "@context": [
    "https://schema.org",
    "https://uri.etsi.org/ngsi-ld/v1/ngsi-ld-core-context.jsonld"
  ],
  "id": "urn:ngsi-ld:Floor:001",
  "type": "Floor",
  "category": {
    "type": "Property",
    "value": "Office"
  },
  "name": {
    "type": "Property",
    "value": "Floor 1"
  },
  "floorNumber": {
    "type": "Property",
    "value": 1
  },
```

- Every physical construct is modeled as an "entity" in the NGSI-LD.
- Each entity will have its own specified context and that users can develop robust ontologies customized to their specific needs

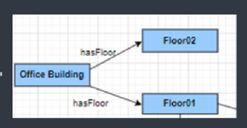
Properties/ Values

```
"Lighting Level": {
  "type": "Property",
  "value": 800,
  "unitCode": "LUX",
  "observedAt": "2024-01-23T12:00:00Z"
}
```

- Each attribute seeks to describe an entity and should mimic how we understand the physical entity in the physical world
- Eg. LEDLight_01 (an entity) has a property Lighting Level (a property) has a Lighting Level Lux (Value)

Relationships

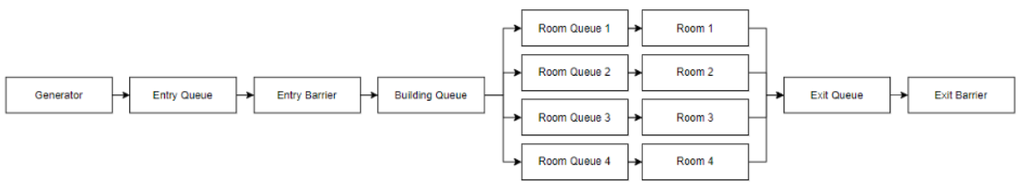
```
//Office Building Entity
{
  "@context": [
    "https://schema.org",
    "https://uri.etsi.org/ngsi-ld/v1/ngsi-ld-core-context.jsonld"
  ],
  "id": "urn:ngsi-ld:Building:001",
  "type": "Building",
  "category": {
    "type": "Property",
    "value": "Commercial"
  },
  "hasFloor": {
    "type": "Relationship",
    "object": "urn:ngsi-ld:Floor:001"
  },

  "name": {
    "type": "Property",
    "value": "Smart Office Building"
```



- Relationships exist between Entities, Properties, and Value to establish a connection between different instances using Linked Data.
- Eg. One of the attributes of the Office Building Entity is a relationship attribute of the nature "hasFloor", which then list Floor01 as an object of the relationship

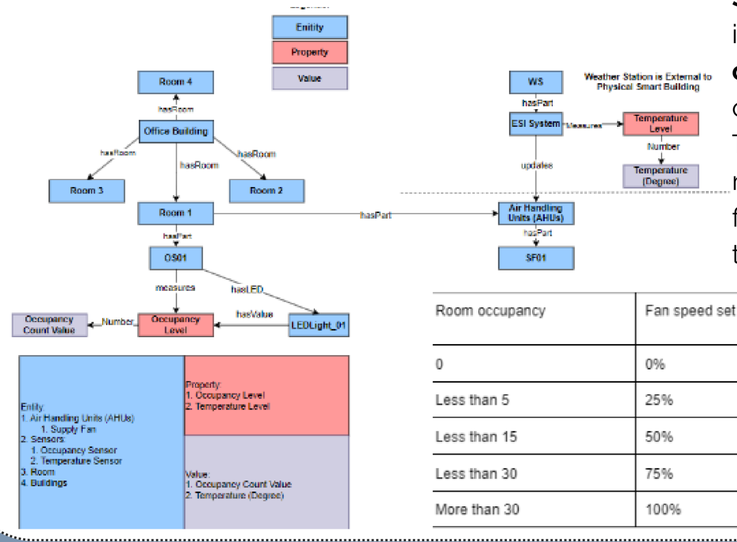
HVAC System Simulation Model

Situation without real-time information model



Generator: "generates" working staff that enter into building. Based on average arrival rates of people into building.
Entry Barrier: A barrier where a working staff taps their staff card to enter building. Should there be huge inflow of people, an entry queue will be formed right before the entry barrier.
Staff moves into their preferred room via tapin. Similarly, if there is huge influx of people awaiting to enter a room, a small room queue will be formed.
Working staff will stay for an assigned period of time before exiting building

Situation with real-time information model



Same process flow as without real-time information model, but **include the collection of real-time data** on outside temperature and occupancy at **30-minute intervals**
The fan speed of the aircon is adjusted at 30-minute intervals by taking the average of the 2 fan speed set for the 2 conditions as shown in the table below

Room occupancy	Fan speed set	Difference in outside temp. To set temp.	Fan speed set
0	0%	Less than, equal 0	0%
Less than 5	25%	Less than 1	25%
Less than 15	50%	Less than 2	50%
Less than 30	75%	Less than 3	75%
More than 30	100%	More than 3	100%

Results from both simulation model

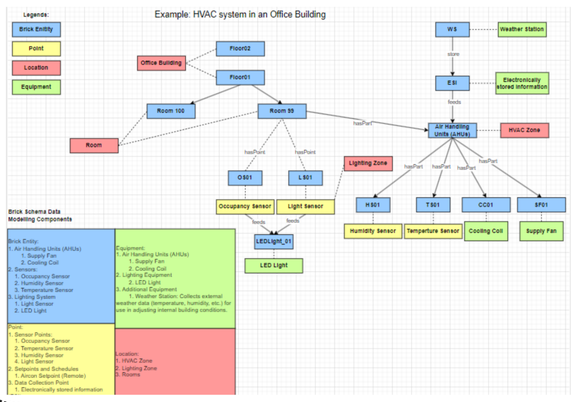
	Aircon 1			Aircon 2			Aircon 3			Aircon 4		
Timings	Non-informational	Informational	Savings	Non-informational	Informational	Savings	Non-informational	Informational	Savings	Non-informational	Informational	Savings
0001-01-01 00:00:00	100	0	100	100	0	100	100	0	100	100	0	100
0001-01-01 00:30:00	100	75	25	100	75	25	100	75	25	100	75	25
0001-01-01 01:00:00	100	87.5	12.5	100	87.5	12.5	100	87.5	12.5	100	87.5	12.5
0001-01-01 01:30:00	100	87.5	12.5	100	87.5	12.5	100	87.5	12.5	100	87.5	12.5
0001-01-01 02:00:00	100	87.5	12.5	100	100	0	100	87.5	12.5	100	100	0
0001-01-01 02:30:00	100	87.5	12.5	100	87.5	12.5	100	87.5	12.5	100	87.5	12.5
0001-01-01 03:00:00	100	87.5	12.5	100	87.5	12.5	100	87.5	12.5	100	87.5	12.5
0001-01-01 03:30:00	100	87.5	12.5	100	87.5	12.5	100	87.5	12.5	100	87.5	12.5
0001-01-01 04:00:00	100	87.5	12.5	100	87.5	12.5	100	87.5	12.5	100	75	25
0001-01-01 04:30:00	100	75	25	100	75	25	100	75	25	100	75	25
Total	1000	762.5	237.5	1000	775	225	1000	762.5	237.5	1000	762.5	237.5

Skill Sets Acquired

- Deeper understanding of various information models and their applications
- Gain proficiency in using context broker as an API for extraction and updating
- Grasp the essential role of context broker in cross-system data reconciliation
- Gain proficiency in utilizing Python for coding simulation models with and without the integration of information models

Comparison between NGSI-LD VS BRICK Schema

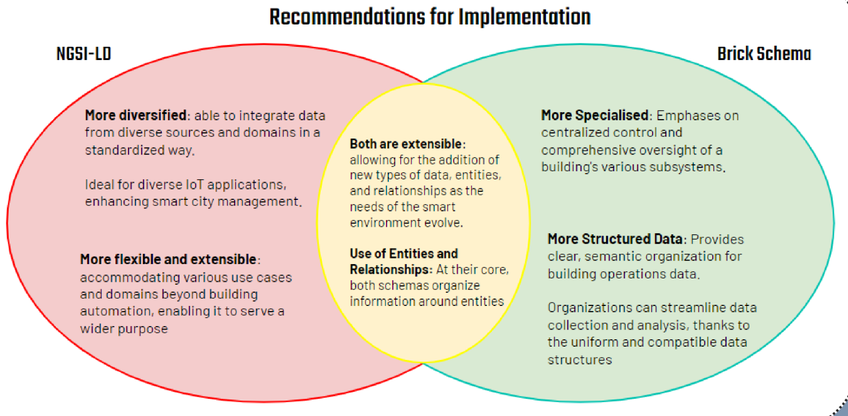
BRICK Schema



Comparison between NGSI-LD & BRICK Schema

Feature	NGSI-LD	BRICK Schema
Foundational Principles	Based on Linked Data principles for integrating diverse data sources in a standardized way.	Provides a semantic data structure for centralized control and oversight of building subsystems.
Main Focus	Tailored towards IoT applications, particularly in smart cities and data communications.	Emphasizes on building management systems and operations.
Challenges	It treats all components as entities can complicate comprehension and execution without visual aids, lack flexibility Scalability issues arise with large-scale deployment due to constant updates	Specialized IoT devices with unique metrics may need significant schema customization, which could add complexity and typically requires manual intervention. It rely heavily on a predefined set of relationships. Hence, modeling unique or non-standard relationships could pose challenges
Implementation Complexity	May require visual models for easier understanding and implementation, especially for large-scale deployments.	Has a steep learning curve for newcomers due to its specific method of representing data and relationships.
Suitability	Better suited for modeling IoT devices capable of interacting with a central network.	Optimized for structured management and operation of building systems, requiring less data consolidation.

Recommendations for Implementation



Conclusion

- Illustrated the proof of concept of information models in smart buildings by developing an NGSI-LD entity-relationship diagram and accompanying NGSI-LD code for entities and relationships for the HVAC system in smart buildings.
- Shown improvement in system performance without the information model and under the information model.
- Concluded that the NGSI-LD model could be more scalable and facilitate cross-agencies work due to context brokers that can facilitate interoperability

Recommendation

- Securing access to comprehensive and authentic application data as it would be essential for validating the efficacy of the developed information model in real-life contexts. .
- Propose that the SNDGO lead the efforts into building a library of entities that allows various ministries and statutory boards to build cross-agency models for enhanced scalability and interoperability