Engineering IoT Systems: Through the Lens of Smart City Living Lab

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My Research

**Areas:** Self-adaptive architectures, software architecture, ML-enabled systems, MLOpS,..

**Domains:** microservice systems, IoT systems, CPS,..
Smart Cities
What is a Smart City?

A smart city is a municipality that uses **information and communication technologies (ICT)** to increase **operational efficiency**, share **information with the public** and **improve** both the **quality** of government services and citizen welfare.

*Source: techtarget*
Engineering Smart City: Key Challenges

1. IDC – Global spending on smart city projected to reach 158 billion USD

2. UN - By 2050, 68% of the world’s population is expected to live in urban areas

3. Smart City technologies can reduce energy consumption in buildings by 30%

4. Traffic congestion can be reduced by 30% through smart parking systems

5. Green house emission reduction by 15%

6. ....
But..How to get Started?

Living Lab Model
The Living Lab Model

• Campus a “live” lab to seed, test and prove innovation before taking them into cities
• Connect. Share. Discover.
• A place for all stakeholders to meet and converse on possibilities, challenges and solutions
• IIITH Living Lab setup by Meity, Smart cities mission and Govt of Telangana
• With knowledge support from EBTC and AIA
The Big Challenge: Interoperability and Heterogeneity
Sensor Verticals and requirements

- Weather
- Air Quality
- Water Quality and Quantity
- Energy Monitoring
- 4G, LoRa, WiSUN, 5G
- Smart House
- Crowd Monitoring
- Smart Lamp
Engineering Smart City: Key Challenges

1. Each Sensor nodes may use different protocol – MQTT, HTTP, COAP,..

2. Support for different communication channels – Wifi, 4G, LoRA, etc.

3. Nodes may fail - Hardware issues or software issues

4. Adding new node should be a hassle-free process

5. Near-real time visualizations, data also needs to be sent to multiple stakeholders
Sensor Nodes
Framework for Interoperability
The OneM2M Standard

Source: onem2m.com
The OneM2M Standard

Standard defined and maintained by body consisting of members from US, Japan, Europe, India, Korea, China, etc

Source: onem2m.com
Putting it Together
Smart Campus Overview

- Weather
- Air Quality
- Water Quality and Quantity
- Energy Monitoring
- Smart House
- Crowd Monitoring
- Smart Lamp

OM2M
Connecting things

API Connector

Data Lake

API Connector

5G
4G
LoRa
WiSUN

INDIA URBAN DATA EXCHANGE
Zooming in Further

- Multiple IoT nodes post data to the **Data Monitoring Layer (DML)** at predefined intervals depending on the parameters being monitored.

- The DML forwards this data using the subscription-notification CSF of oneM2M to the **Data Storage Layer (DSL)**.

- The data can be subsequently accessed by registered clients through the APIs in **Data Exchange Layer (DEL)**.
Zooming in Further
Visualization
Data Visualization Features

Fetch periodic data from onem2m cloud

Display nodes deployed and vertical parameters

Web frontend and mobile app to view locations on map and relevant sensor data

Backend to store and process nodes and vertical data

Run analytics on the data captured

Generate visualization diagrams and graphs

Provide summary view, 3D view and Map view with Analytics for easy visualization
Node Maintenance – Handling uncertainties

- Data quality validation, outlier detection, and systematic reporting
- Send an email to respective authority to report the node health
- Validation of the subscription resource and notification
- To assess the servers' status and notify

The tentative scope of the framework, as per our initial understanding.
Reference Stack Built

- Water, Energy, Solar, Pollution, Weather, Occupancy/crowd management sensor data
- Multiple communication networks
- OM2M layer, a horizontal M2M service platform
- Data lake comprising of OM2M and Data warehouse
- Standard Data and Information models with IUDX as a data interchange layer
- Standardized view of all sensor data
- Data availability to multiple stakeholders including Research, Govt etc.
Looking into the Future
Ongoing and Future Works

1. Migration of architecture to support larger scale - Self-adaptation
2. Integration of 5G – Crowd Management and water quality management
3. Digital Twins – Water Center of Excellence with Hyderabad
4. Maintenance dashboard and alerting system development
5. Interoperability layer analysis
6. WiSun Deployment with Silicon Labs
7. Many more core research works on water, Air, Smart Energy, .....
Partners and Leadership
Founding Partners, In-Place and Engaged

Key Stakeholders

Corporate Partners

SME/Startup Partner

Knowledge & Research Partners

20 Centers of Excellence

Technology Partners
Leadership Team

Aftab Hussain  Ramesh Loganathan  Vishal Garg  Sachin Chaudhari

Anuradha Vattem  Deepak Gangadharan  Karthik Vaidhyananthan  Prakash Yalla
Publications

• Sai Usha Nagasri Goparaju, SVSLN Surya Suhas Vaddhiparthy, Pradeep C, Anuradha Vattem, Deepak Gangadharan "Design of an IoT System for Machine Learning Calibrated TDS Measurement in Smart Campus", accepted in WF-IoT 2021
• S. Deb, C. Rajashekar, S. Chaudhari, K. Vemuri, K. S. Rajan, "IoT Network-Based Analysis of Variations in Particulate Matter Due to COVID-19 Lockdown", accepted in CONECCCT 2021
• C. Rajashekar, S. Chaudhari, "Hierarchical Clustering based Spatial Sampling of Particulate Matter Nodes in IoT Network", accepted in WF-IoT, 2021
• I. Patwardhan, S. Sara, S. Chaudhari, "Comparative evaluation of new low-cost particulate matter sensors", accepted in FiCloud 2021
• Shubham Mante, Rathwik Muppala, D. Niteesh, Aftab M Hussain "Energy Monitoring Using LoRaWAN-based Smart Meters and oneM2M Platform", accepted in Sensors 2021
• Deeksha Devendra, Shubham Mante, D. Niteesh, Aftab M. Hussain "Electric Vehicle Charging Station using Open Charge Point Protocol (OCP) and oneM2M Platform for Enhanced Functionality", accepted in TENCON 2021
• Shubham Mante, Nathalie Hernandez, Aftab Hussain, Sachin Chaudhari, Deepak Gangadharan and Thierry Monteil "SD-IoT, a Semantic Web Based Framework for Assessing IoT Data Quality", accepted in 37th ACM/SIGAPP Symposium On Applied Computing (SAC), 2022
• Md Anam Raha, Kuntal Chattopadhyay, Aviruch Bhatia, Vishaal Garg, Aftab M Hussain "Energy analysis of semi-transparent building integrated photovoltaic window in Hyderabad, India using automated parametric simulations", accepted in ICSRRIE 2021
• Shubham Mante, SVSLN Surya Suhas Vaddhiparthy, Muppala Rathwik, Deepak Gangadharan, Aftab M Hussain, Anuradha Vattem "A Multi Layer Data Platform Architecture for Smart Cities using oneM2M and IUDX", accepted in WF-IoT 2021
• Sai Usha Nagasri Goparaju, SVSLN Surya Suhas Vaddhiparthy, Pradeep C, Anuradha Vattem, Deepak Gangadharan "Design of an IoT System for Machine Learning Calibrated TDS Measurement in Smart Campus", accepted in WF-IoT 2021
• A. Kumar Lall, A. Khandelwal, N. Niles, S. Chaudhari "Improving IoT-based Smart Retrofit Model for Analog Water Meters using DL based Algorithm", accepted in FiCloud 2022
• Rishikesh Bose, Ayu Parmar, Harsha Narla, Sachin Chaudhari "Comparative Evaluation of Low-Cost CO2 Sensors for Indoor Air Pollution Monitoring", accepted in WF-IoT 2022
• A. Kumar Lall, A. Khandelwal, R. Bose, N. Bawankar, N. Niles, A. Dwivedi, S. Chaudhari "Making Analog Water Meter Smart using ML and IoT-based Low-Cost Retrofitting", accepted in FiCloud 2021

Patents

• "Low cost retrofit for digitisation of analog water meter," Rishikesh Bose, Niles Bhawankar (Under Review (3rd level verification))
• "Air quality monitoring device for monitoring an air-quality with less energy consumption," Prof. Sachin Chaudhari, Rajashekar Reddy Chinthlaapani, Ayu Parmar, Ayush Dwivedi, Niranjan Keesara, Mahesh Murty (Applied for all India patent)
Thank you