IoT Edge Systems with IEEE 21451 Standards

A Perspective of Experiential Learning

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Overview of IoT

Internet of Things (IoT) and applications is an emerging field for both business and technology advancement. IoT is a new class of applications that require integration of several technologies. Industry is taking advantage of IoT to improve the bottom line as well as top line. Rolling out of IoT applications are quite challenging (integration of several technologies) and time consuming (finding appropriate technology and applications), resource intensive (R&D staff) etc. In this technical report, we focus on IoT Edge Systems with IEEE 21451 family of standards.

What Customers are looking for at the IoT Edge (Business Opportunities)

From our study, we find rolling out a generic IoT solution is not advisable. Also, it is difficult to provide a full solution from a single vendor or technology. IoT demands integration of products and services from different vendors and harmonizing business services, scaling of the deployments and securing the IoT deployments and more. IEEE 21451 family of standards enable IoT systems with a focus on interoperability and harmonization of services.

I would like to present a brief summary of several interactions with the customers and their requirements that influence the systems architecture and design of IoT systems.

#1 New Technology Adaptation

Understanding the new IoT technologies with a focus on the problem they are facing. Customers are not very interested to see a generic IoT solution in project proposals. For example, customer who are looking for IoT applications for CNC machines, want to see their problems in the project proposal. So, IoT Engineers have to study the customer domain and propose business viable solution.

#2 IoT Edge Software Infrastructure

Customer are looking for Software stack for their Engineering staff to develop IoT applications. Though developing a software stack for IoT Edge is not impossible, it is not easy though. Engaging right engineering staff to develop IoT Edge software is becoming expensive as it it not their (customers') focus. Customers are looking for some initial lead on using IoT Edge Software stack.

#3 Firmware and BSP for Smart Transducers

Customer are looking for Firmware, Board Support Packages stack for their Engineering staff to develop IoT applications. Though developing a Firmware stack for IoT Edge is not impossible, it is not easy though. Customers are looking for some initial lead on using IoT Edge Firmware stack.

#4 Dataflow Design at the IoT Edge

Designing the data collection from 'Things', streaming the data to service gateways (*NCAP of IEEE 21451-1*) and performing certain operations on the data at the Edge needs 'Design Thinking' approach. Every IoT deployment is unique - as far as Dataflows are concerned. Customer are looking for Dataflow designs at the Edge however there may be some exceptions and/or similarities.

#5 Mix in of Automation and IoT

Customer often mix Automation and IoT applications. It is quite natural to have excursions between Automation and IoT, however, IoT is predominantly information related. Customers often looking for some consultative approach in rolling out Digital technologies. IoT uses automation technologies to deliver *smart factory applications*. It should be noted that IoT is not a 'replacement' for Automation technologies until full roll of Industry 4.0.

#6 IoT Station for Edge Data Processing

In practice, there are Engineering Stations, Operator Stations in a factory environment. Deploying cost-effective data centric applications (data processing, visualization, dataflows etc.,) is quite challenging at the Edge. An IoT Station (Information Processing Station) is something that customers are envisioning in addition to Engineering and Operator stations.

#7 Information Audit Applications

IoT application are new and emerging with a focus on information processing and data driven decisions. Information auditing at the IoT Edge is increasingly in demand. For example, applications such as quality audit using IoT, smart

inventory, smart feedback, real-time profit control, cascade of operations performance loops, asset utilization, asset availability etc.

#8 Network Capable Applications at the IoT Edge
Customers are looking for network based applications that integrate with other systems easily (*harmonization of services*). Such applications require lot of effort even to build a PoC. Customers prefer piloting a smaller scale version before rolling out a sizeable IoT deployment.

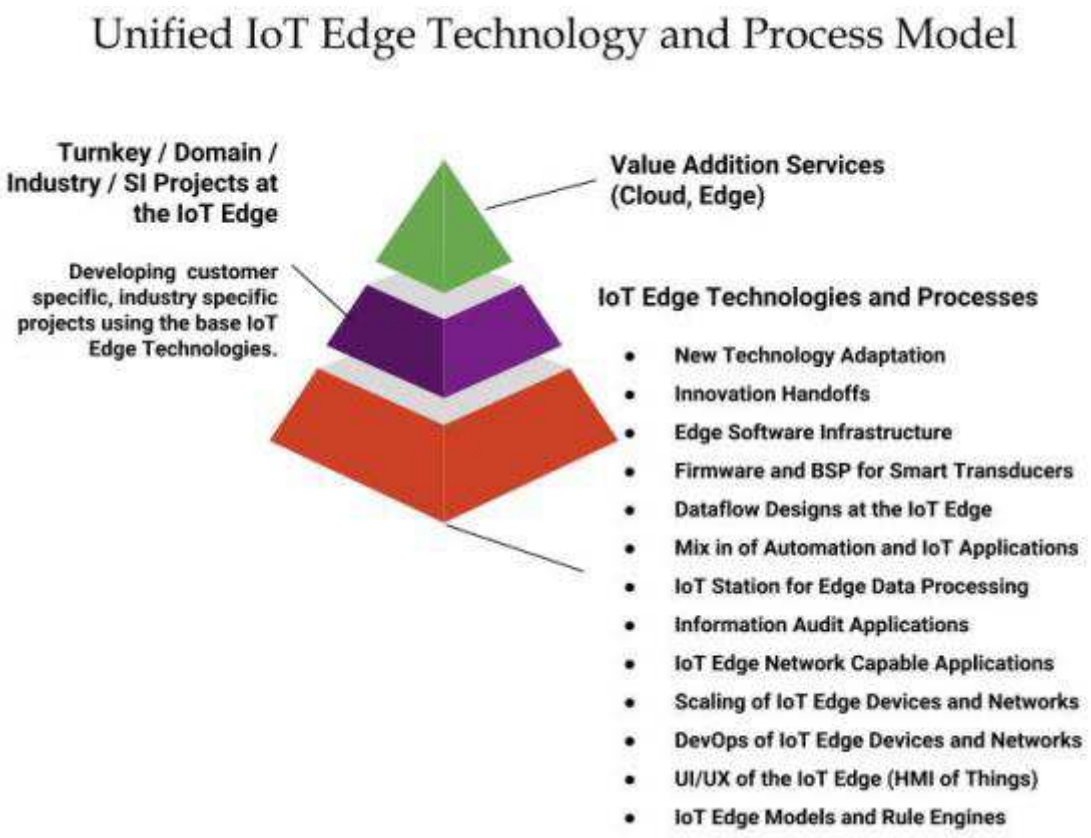
#9 Scaling of IoT Edge Devices and Networks
IoT is emerging field and require careful planning to scale the IoT applications. Customers are looking for PoC with scale as objective - at least with simulations. For example, size of IoT nodes, network reliability, power distribution, remote servicing of IoT nodes etc. A careful design of IoT systems should address the scale issues.

#10 DevOps of the IoT Edge
Managing the IoT devices is quite challenging; unique for every IoT deployment. Customers are looking for solutions to manage IoT DevOps.

#11 User Experience at the IoT Edge
The current HMI of Automation was built with a focus on controllability of equipment whereas HMI of IoT is information centric; the HMI of IoT needs a fresh approach to deliver user experience (UX).

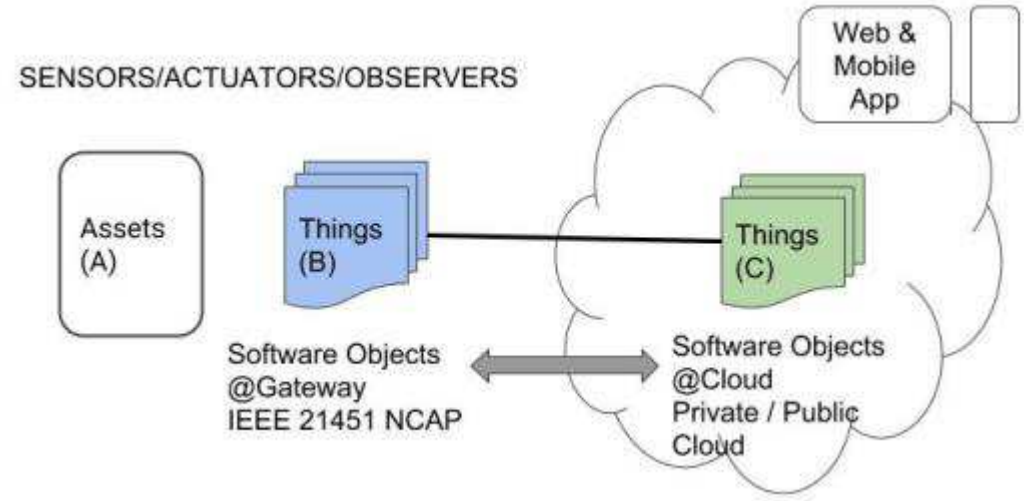
#12 Cyber-Physical Models, Rule Engines at the IoT Edge
IoT is mainly for building connected applications. The outcome of connected applications depends on the information models that the Edge devices process.

The following diagram depicts mapping of the above requirements to an implementation model.



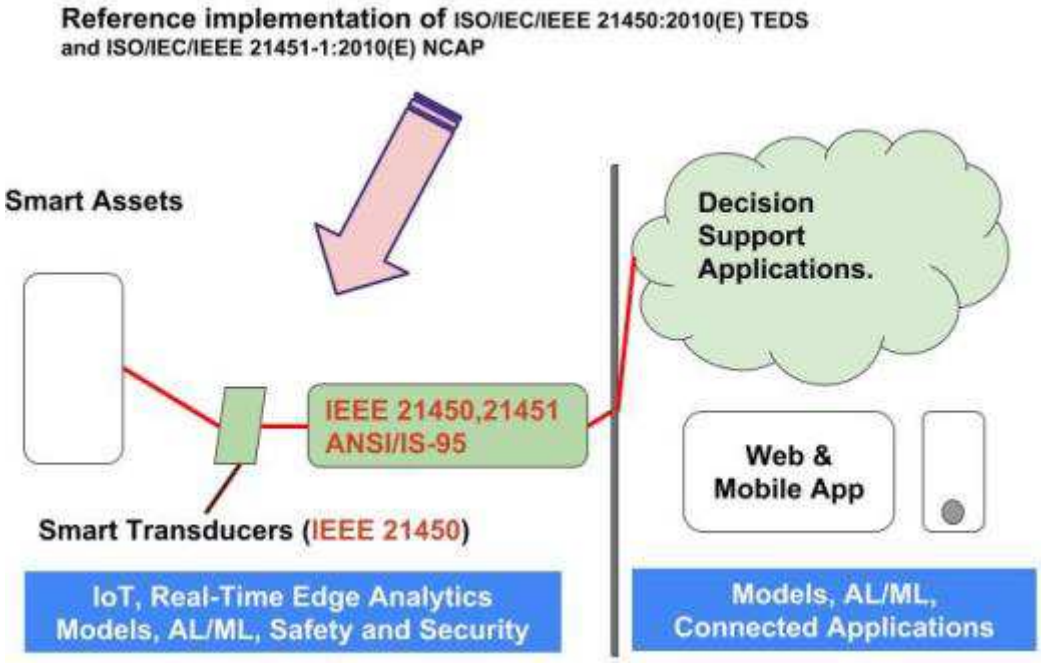
What to identify as "Things" in IoT? "Assets" are " Things"

What do qualify as things at least in a business context? This is a question we often encounter in the design of an IoT Gateway while working on a reference implementation of the ISO/IEC/IEEE 21450:2010(E) TEDS and ISO/IEC/IEEE 21451-1:2010(E) NCAP. IoT is applicable to all business where "**assets**" are interconnected and interoperated with energy, material and **information**. The assets vary from business to business or event within a business itself. So, any '**asset**' that creates a business value is the primary candidate to become a '**thing**'.



The above diagram simplifies the overall concept of transforming 'assets' to 'things'. The Edge Gateway (IEEE 21451 NCAP) plays an important roles in enabling 'Things' and transacting with the assets in real-time.

Implementation Notes of IEEE 21451 NCAP as IoT Gateway



IoT Gateway (IEEE 21451 NCAP) consists of @Edge, @Cloud parts. @Cloud deals Digital Twins, User interactions, Visualization etc. IoT Edge Gateway is an 'intelligent agent' that provides smart asset data to @Cloud applications. Here is a list of open standards, open source software libraries to implement IoT Edge Gateway.

Edge Hardware Platform:

- Single Board Computers such as Raspberry Pi, Beaglebone or any Linux supported platforms.

Edge Architecture Standards and Specifications:

- ISO/IEC/IEEE 21450:2010(E) TEDS
- ISO/IEC/IEEE 21451-1:2010(E) NCAP (Gateway Architecture)
- ANSI/ISA-95 <- For interfacing with industry controls

Edge Communication Standards and Specifications:

- Websockets (RFC 6455)
- XMPP (open standard for messaging and presence)
- RESTful Web services with HTTP/1.1 and HTTP /2
- Open SSL / TLS
- Dynamic DNS (DDNS or DynDNS) (for discovering / accessing IoT Edge Gateway nodes).

- OSGi <- For Service life cycle management
- AMQP
- ZeroMQ (though it is not a full standard but widely used messaging framework)

Edge Smart Device Connectivity Standards and Specifications:

- I2C <- To connect smart transducers
- SPI <- To connect smart transducers and interface boards (Smart Assets)
- Modbus TCP and Modbus RTU
- RS-485 <- For multi-drop serial communication
- CAN

Edge Device Storage Standards and Specifications:

- HDF5 - Hierarchical Data Format (HDF) is a set of file formats (HDF4, HDF5) designed to store and organize large amounts of data.

Edge Data Security and Cryptography

- Libsodium - easy-to-use software library for encryption, decryption, signatures, password hashing and more

Edge Programming Languages

- C, C++11 / 14

Edge Open Source Software Libraries

- libmicrohttpd (Embedded webserver)
- libwebsockets (Websockets)
- cURL
- zmq (ZeroMQ messaging library)
- libsodium (Crypto library)
- hdf5 (https://www.hdfgroup.org)
- POCO C++ (Useful set of C++ libraries)
- GSL (GNU Statistical Library) for edge statistics
- BLAS for linear algebra and low level matrix operations.
- LAPACK - (a standard software library for numerical linear algebra)
- Silicon - A high performance, middleware oriented C++14 http web framework http://siliconframework.org
- uriparser (RFC 3986)
- json11 (for handing JSON data)
- Vue.js (for web front-end interface)
- yaml-cpp (YAML for defining TEDS)
- Swagger (for API documentation and specification)

Edge Open Source Software IDEs

- CodeLite (https://codelite.org/)

Conclusion

IEEE 21451 family of standards provide interoperable, and service harmonization framework and patterns. Implementing the full standards may not be required; good parts of the standard can be used designing IoT systems.

About the author

Maruthi is a founder director of Vidcentum R&D where he manages the following product lines: Picominer® - IoT Gateways and Edu-Fi® - Platform for online workshops. Prior to founding Vidcentum R&D, Maruthi worked in Airvana Networks, Telsima Communications, Satyam Computer Services. Maruthi is a Senior Member of IEEE and an active volunteer of IEEE. He served as Secretary, Treasurer, Chairman Computer Society Chapter, Vice Chair and Chairman of IEEE Hyderabad Section. Maruthi participates in development of IEEE 1451-99 Standard for Harmonization of Internet of Things (IoT) Devices and Systems. He also teaches Data Mining to Masters students of BITS Pilani Work Integrated Learning Programmes in Hyderabad. Maruthi can be reached at: maruthi@vidcentum.com | pvsmaruthi@ieee.org | +91 9052512020

Microsoft will release a software update for 'Windows 7' operating system with a warning, "After 10 years, support for Windows 7 is nearing the end." Microsoft had earlier said users can still use Windows 7 but PCs "will become more vulnerable to security risks" after all support ends on January 14, 2020. Windows 7 was first released in October 2009.