Device Ecosystem at the Edge - Manufacturing Scenario

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INTRODUCTION

Any manufacturing setup, whether discrete or process, has a large number and variety of machines and assets. These include production machines, robots, conveyors, process equipment, utilities such as chillers, cooling towers, instruments and many others. Last but not the least, it includes people! So the 'Edge' is pretty colorful!

'Smart Manufacturing' denotes a manufacturing paradigm that creates and uses data generated from machines and other sources to achieve high productivity and quality as well as respond rapidly to changes in demand. This is achieved by the convergence of Operations Technology (OT), Information Technology (IT), Industrial Automation & Control Systems (IACS), Networking and Communications.

Many of the Smart Manufacturing systems concentrate only on the main production equipment. But that is not enough. To make the shop floor truly 'Smart,' an Industrial Internet of Things (IIoT) system has to include the entire manufacturing landscape in the set up consisting of machines, assets, devices and people.

EDGE ECOSYSTEM

Let us take a look at different types of 'devices' living in the Edge. We will use the term 'device' in a broad sense to represent anything that is connected to an Edge Gateway. We will categorize devices as follows:

1. **Production Device** – These are production machines / assembly lines / process lines that carry out operations on the raw material / intermediate products to produce intermediate products / final products.
2. **Supporting Device** – These are machines / components that help the production process such as robots, conveyor belts, etc. Supporting devices include bar code / radio frequency identification (RFID) readers, cameras, etc.
3. **Utilities** – These provide required resources including energy for production and also chillers, cooling towers, boilers, compressors, etc.
4. **Test Device** – Various testbeds, instruments and gauges used in testing and calibration.
5. **IIoT Human Machine Interface (HMI)** – IIoT HMI represents people at the Edge. This can be an HMI, a mobile / tablet or even a wearable device (We call it IIoT HMI to differentiate it from the HMI of the machines).

More categories may be discovered as one explores the Edge Ecosystem.

Device Composition

The device as perceived by a user may be comprised of multiple components, each connected separately to the gateway. For example, an Injection Moulding Machine may be comprised of the following: machine PLC (OPC UA), temperature controller (4-20 mA signal), dehumidifier (4-

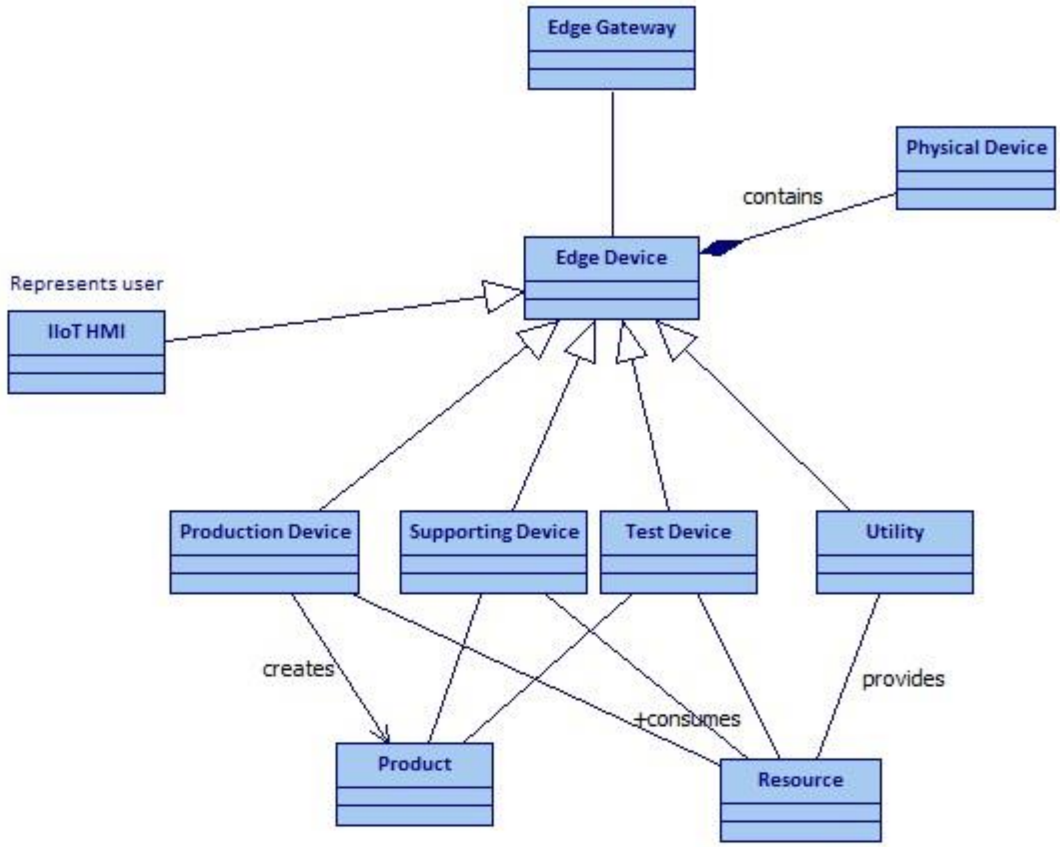

Figure 1: Edge Object Model

20 mA signal), energy meter (Modbus RTU), etc. Protocols supported by each device are shown in (parentheses). For the gateway, there are 4 'physical devices,' each having its own connection and protocol. But for the IIoT system user, this is a single aggregated device, 'injection molding machine.' In fact, the user may not even be aware of the existence of these separate physical devices.

Edge Object Model

With the above considerations, our Edge Object Model looks something like the model reflected in Figure 1.

EDGE PROCESSING

Each Edge Device shown in the model above is continuously generating data about its status, values of different parameters affecting the production such as temperature, pressure, current, etc. and production data such as cycle time and parts produced, etc. But the Edge is not just about data generation. Local processing at the Edge is critical to ensure real-time decision making. Thus, a smart manufacturing system should manage among other things:

- Edge workflow
- Local high-level control like GO/ NO GO
- Edge analytics

- Asset condition monitoring

Edge Workflow

This is an often neglected area. But for continued and sustained usage of the system in the long term, it is absolutely essential that the usage is integrated into shop floor standard operating procedure (SOP). For this, a smart manufacturing system has to understand shop floor workflow and sync with it.

This necessitates incorporation of multiple behavior models for the above data model. Each behavior model defines behavior of each device type, their interactions with each other and with people.

The data model may expand due to further specialization within a device type based on its behavior: For example, specialization of Production Devices into bulk production and tool room machines.

Furthermore, a **Workflow Modeler** is needed to model interactions. This is comprised of a rule engine and a set of pre-defined or custom actions. The Workflow Modeler will manage production schedule, interlocks to control operations flow and user actions, triggers to initiate systemic and extra-systemic messaging, etc. It allows the IIoT system to take contextual decisions in real-time and exercise a required degree of control over the devices, people and their interactions.

Implementation of the workflow modeler will be done in platform tier (cloud / on-premises) or Edge or, most likely, in combination.

Let us look at a specific use case from discrete manufacturing.

Manufacturing Use Case

A factory manufacturing auto components has the following devices (only devices relevant to our discussion are listed):

- Injection molding machine (Edge device)
    - Injection molding machine (Production device)
    - Dehumidifier1 & Dehumidifier2 (supporting device) – only one active at a time and the other is on standby
    - Energy meter (supporting device)
    - HMI (IIoT HMI)
- CNC machining center (Edge device)
    - CNC machining center (Production device)
    - Energy meter (supporting device)
    - HMI (IIoT HMI)
- Surface grinder (Edge device)
    - Surface grinder (Production device)
    - Energy meter (supporting device)
    - HMI (IIoT HMI)
- Cooling system (Utility)
- Pick and Place Robots (supporting device)
- Assembly line machine 1 (Production device)
- Assembly line machine 2 (Production device)
- Vision system (Test device)
- Laser label printer (Production device)
- Conveyor belt (supporting device)
- HMI for assembly line (IIoT HMI)

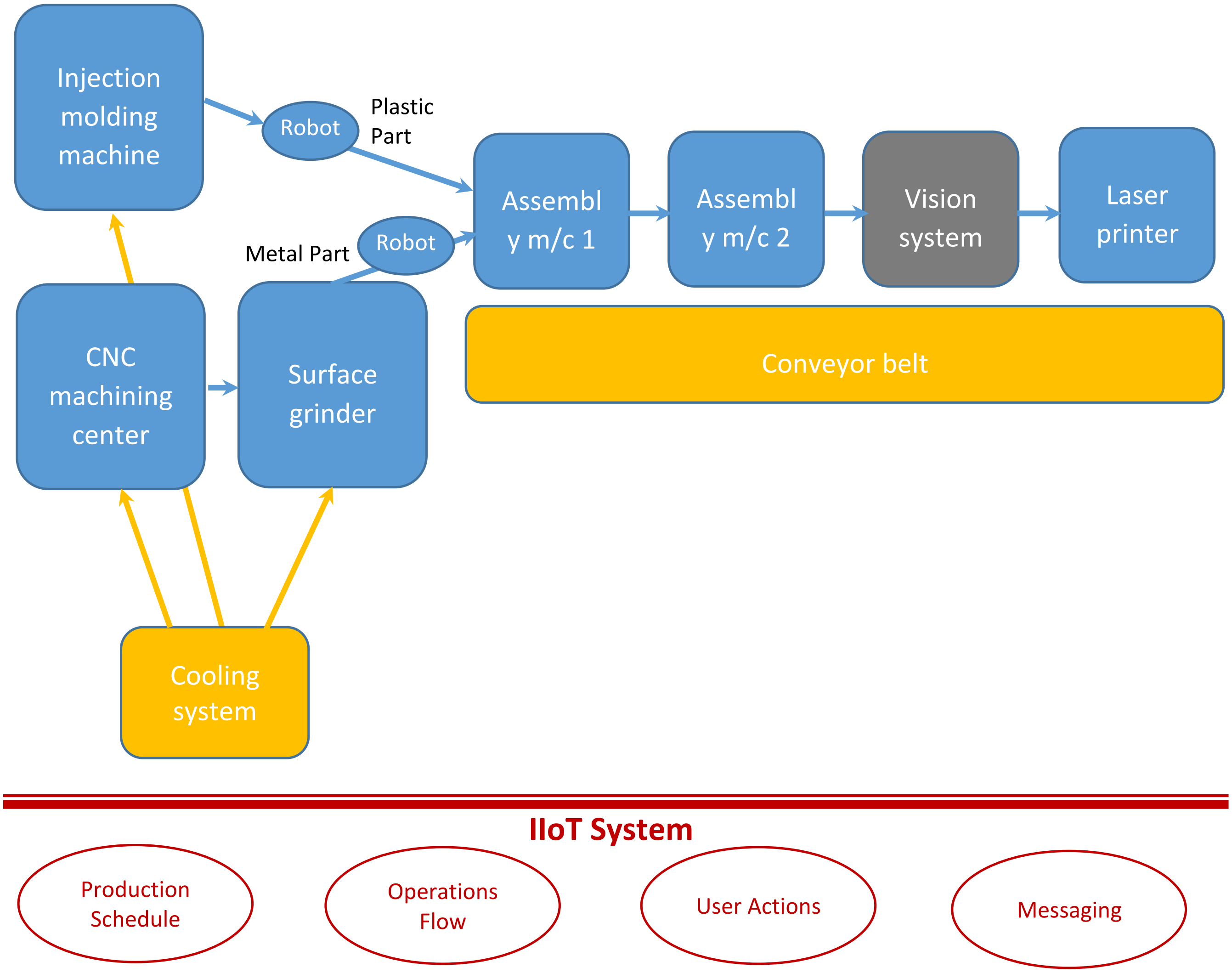

Figure 2: Workflow Block Diagram

The diagram in Figure 2 depicts the workflow.

The following are some of the workflow rules / behaviors that should be incorporated / captured in an IIoT system:

1. Cyclic behavior of production devices. See figure 3.
2. Sequence of operations on metal parts.
3. Timely alerts required to ensure availability of parts and additional components at each stage of assembly.
4. Ensure that the operator enters downtime reason for any device before it is restarted.
5. Capture minor stoppages of machines and raise appropriate alerts in real-time.
6. Capture the results of testing by vision system, reasons for rejection and raise appropriate real-time alerts for improvement.
7. Regulation of cooling system output depending upon the amount of equipment running. Note that cooling systems may be supplying coolant to

much more equipment than the set shown here.

Let us take an example of a Workflow Modeler of a Smart Factory solution. It allows users to incorporate rules like these. For example, #4 is enforced by adding a relay in the machine start circuit. This relay is controlled by HMI based on machine status and user input. Another example is #5 – minor stoppages are captured by the Edge software and sent to the server. The server analyzes the data stream and raises alerts based on the rules configured by user.

IIoT HMI

The workflow described in the previous section requires shop floor users to interact with the system and provide real-time inputs. How do they interact with an IIoT system without affecting their productivity? Also, how do they get the value from an IIoT system in real-time when they are working on the shop floor? IIoT HMI is the solution and an important part of the Edge Ecosystem. It will have direct connectivity (wired or wireless) to the Edge Gateway, allowing it to provide output, even when the server link is down. It shows real-time analytics to users. More importantly, users provide real-time inputs to the system via HM (e.g. product change entry, downtime reasons entry, etc.).

An important characteristic of HMI is its easy accessibility to the user on the shop floor. So a mobile or wearable device is preferable.

Edge Analytics

The Edge Gateway should be capable of doing some minimum and essential stream analytics to ensure value to users even when the link to the server is down. In addition to network challenges, the speed of dissemination of actionable output will necessitate a local loop, rather than going via the server. Of course, we will never miss capturing this and using it for machine learning and analytics at the server level. Some of the typical conditions could include capturing actual production and comparing expected versus actual production, raising critical alarms which need instant attention, trends of parameters, etc.

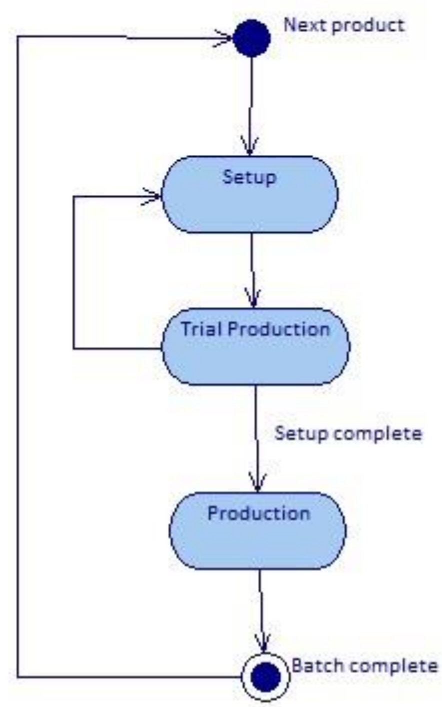

Figure 3: Production Equipment Behavior

Asset Condition Monitoring

Asset condition monitoring and predictive / prescriptive maintenance are an important part of IIoT offerings. The condition monitoring module must have the capability of handling not only production equipment, but all types of assets. In this context, the following are required:

1. Able to look at a group of physical devices as a single asset
2. Handle complexities like standby physical devices.
3. Consider workflow and inter-dependencies of assets when managing / suggesting maintenance activities.

CONCLUSION

In conclusion, the Edge is a very important part of any IIoT system and understanding its intricacies is crucial. Smart manufacturing systems must map the data and behavior models of the shop floor. It should also map shop floor workflow so as to take contextual decisions in real-time and exercise some degree of control over the devices, people and their interactions.

Edge processing on the shop floor includes workflow, local high-level control, Edge analytics and asset condition monitoring. IIoT HMI plays a vital role in connecting users to the system without affecting their productivity.

Ascent Intellimation solution **PlantConnect SFactory** incorporates the concepts discussed in this article.

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