Decoupled Digital Architecture for Manufacturing

Andrew Dugenske
Factory Information Systems Director
Georgia Tech Manufacturing Institute
Andrew Dugenske background

Georgia Tech Manufacturing Institute (GTMI)
Factory Information Systems Center Director
• Enterprise manufacturing software systems
• Internet of Things (IoT)
• Roadmaps
• Standards

President, Factory Right
• Manufacturing applications
• Custom software
• Consulting

General
• Mechanical engineering degrees
• Professional engineer
• +30 years experience
Coupled architecture
Not suitable for future IoT factories
Monitoring of similar devices
Monitoring of similar devices
Many machines and applications
Ultimate end point?
"It's very easy to make things difficult."

- Mark Duginske
Decoupled digital architecture for manufacturing

- Database
- OEE
- Predictive Maintenance
- FMEA
- MES
- ERP
- Analytics

Gateways:
- Database Gateway
- OEE Gateway
- Predictive Maintenance Gateway
- FMEA Gateway
- MES Gateway
- ERP Gateway
- Analytics Gateway

Protocols:
- MQTT
- MTConnect
- OPC-UA
- OPC-DA
- ROS
- Modbus
Architecture Technology Stack

- Distributed and decoupled
- Event based vs polling
- MQTT Message Broker
- Follows standard manufacturing data pattern
- Publish and Subscribe to exchange data
- MQTT topic structure pattern (subscriptions and wildcarding)
- JSON message pattern
- Websockets (html 5) for immediate updates
Technical benefits

• Accommodates wide-variety of devices, protocols and applications (Inclusive vs Exclusive)
• Enterprise solution vs ad hoc
• Many-to-many communication
• Built on standards (no proprietary lock-in)
• Most prevalent IoT technologies
• Very Secure
• Extremely scalable
• Highly maintainable
• Simple to use and deploy
• Monitorable and traceable
Financial benefits

• Out of the box solution
  • Configuration vs programming
  • Specialized skills not required (maintenance vs developers)
  • Open source libraries available
• Reduces the types and number of licenses (Ad hoc vs strategic implementation)
• Open source, commercial or cloud
• Students learning these technologies today
• No proprietary lock-out—lower costs
• Partners have demonstrated traceable ROI
• Provides a clear path for legacy equipment
Node-RED machine gateways

MTConnect to Message broker

OPC-UA to Message broker
Node-RED application gateways
MQTT Messages
Modeled from MTConnect, CAMX & Applications

Attribute Definitions:

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>assetId</td>
<td>The Id of the asset. The asset is the machine, device or work cell.</td>
</tr>
<tr>
<td>dateTime</td>
<td>Timestamp for the data</td>
</tr>
<tr>
<td>dataItemId</td>
<td>An additional classification of the data (i.e. MotorCurrent). Definitions from CAMX Standards</td>
</tr>
<tr>
<td>value</td>
<td>The value of the data. This could be numeric or string.</td>
</tr>
<tr>
<td>itemInstanceId (optional)</td>
<td>The item instance is a value that identifies the item (e.g. Serial number, Product type, Lot Id) that is currently being processed.</td>
</tr>
<tr>
<td>operatorId (optional)</td>
<td>The Id of the operator of the machine or device when the data was generated.</td>
</tr>
</tbody>
</table>

JSON Payload:

```
{
    "assetId": "OKUMA-Genos-2 ",
    "dateTime": "2018-09-10T01:36:44",
    "dataItemId": "LpRunningTime ",
    "value": "28828",
    "itemInstanceId": "PartNumber101345",
    "operatorId": "O456001234"
}
```
# Tertiary Manufacturing Data Attributes

<table>
<thead>
<tr>
<th>Field</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>errorId</td>
<td>A unique value for each error type. Primarily for computer interpretation.</td>
</tr>
<tr>
<td>errorDescription</td>
<td>A human readable description of the error.</td>
</tr>
<tr>
<td>errorInstanceId</td>
<td>A unique value for each instance of the error type.</td>
</tr>
</tbody>
</table>
MQTT messages for material movement

**ItemTransferIn**

```json
{
    "dateTime": "2017-02-10T01:26:44",
    "assetId": "work_cell1",
    "dataItemId": "ItemTransferIn",
    "value": "true",
    "itemInstanceId": "PartNumber101345"
}
```

**ItemTransferOut**

```json
{
    "dateTime": "2017-02-10T01:36:44",
    "assetId": "work_cell1",
    "dataItemId": "ItemTransferOut",
    "value": "true",
    "itemInstanceId": "PartNumber101345"
}
```
MQTT messages for material movement

**ItemWorkStart**

```json
{
  "dateTime": "2017-02-10T01:26:44",
  "assetId": "work_cell1",
  "dataItemId": "ItemWorkStart",
  "value": "true",
  "itemInstanceId": "PartNumber101345"
}
```

**ItemWorkAbort**

```json
{
  "dateTime": "2017-02-10T01:26:44",
  "assetId": "work_cell1",
  "dataItemId": "ItemWorkAbort",
  "value": "true",
  "itemInstanceId": "PartNumber101345"
}
```

**ItemWorkComplete**

```json
{
  "dateTime": "2017-02-10T01:36:44",
  "assetId": "work_cell1",
  "dataItemId": "ItemWorkComplete",
  "value": "true",
  "itemInstanceId": "PartNumber101345"
}
```

**ItemWorkResume**

```json
{
  "dateTime": "2017-02-10T01:36:44",
  "assetId": "work_cell1",
  "dataItemId": "ItemWorkResume",
  "value": "true",
  "itemInstanceId": "PartNumber101345"
}
```
MQTT Topic Pattern

Asset/\{assetId\}/\{dataItemId\}

Asset/ANT10012/Temperature

(assetId) \quad (dataItemId)

‘Asset’ is root of topic for easy subscription (vs Control, Broker, $SYS)
Strategic subscribing to MQTT topics

Asset/AN101/ItemWorkComplete

<table>
<thead>
<tr>
<th>Subscription</th>
<th>Single Asset</th>
<th>Single Topic</th>
<th>All Assets</th>
<th>All Topics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asset/AN101/ItemWorkComplete</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset/+/ItemWorkComplete</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asset/AN101/#</td>
<td>X</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Asset/#</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>
MQTT Message to Database Mapping

```json
{
    "assetId": "OKUMA-Genos-2 ",
    "dateTime": "2018-09-10T01:36:44",
    "dataItemId": "LpRunningTime ",
    "value": "28828",
    "itemInstanceId": "PartNumber101345",
    "operatorId": "O456OO1234"
}
```
Payload and topic to database mapping

Asset/OKUMA-Genos-2/LpRunningTime

{  
  "assetId": "OKUMA-Genos-2 ",  
  "dateTime": "2018-09-10T01:36:44 ",  
  "dataItemId": "LpRunningTime ",  
  "value": "28828 ",  
  "itemInstanceId": "PartNumber101345 ",  
  "operatorId": "O456001234 "
}

MQTTLog Table

<table>
<thead>
<tr>
<th>mqttLogId</th>
<th>dateTimeReceived</th>
<th>topic</th>
<th>payload</th>
</tr>
</thead>
<tbody>
<tr>
<td>84669</td>
<td>2018-05-18 14:31:17</td>
<td>Asset/OKUMA-Genos-2/LpRunningTime</td>
<td>{&quot;assetId&quot;:&quot;OKUMA-Genos-2&quot;,&quot;dateTime&quot;:</td>
</tr>
</tbody>
</table>

Generated by database
Application examples
Message Broker Monitoring
Legacy equipment
DMDII IoT retrofit kits

Press tool monitor

Motor monitor
Current Architecture Projects