T2

Tier 2 · Unified Connectivity Hub

User Manual

Operating the Unified Connectivity Hub and Closed-Loop Control

Version	1.0
Status	PRODUCTION
Zone	OT / IT Bridge
Standards	MQTT SparkplugB / OPC-UA IEC-62541 / Modbus TCP / ISA-88
Block Count	7 blocks
Document Date	May 2026

1. Introduction

Tier 2 is the communications backbone of the IIoT Framework. It sits between the OT zone (T1) and the enterprise IT zone (T3), providing protocol translation, namespace construction, enterprise connectivity, and — most critically — the closed control loop via the Action Logic Engine.

T2 consumes the enriched messages produced by T1 and either publishes them upward to enterprise systems or, when the T3 anomaly detection layer fires, sends physical commands back down to machines. This bidirectional capability makes T2 the engineering heart of the Closed-Loop IIoT architecture.

1.1 Block Overview

UNS Builder	Constructs ISA-95-aligned MQTT topic paths from Asset Registry context.
MQTT Bridge (Sparkplug B)	Encodes/decodes Sparkplug B Protobuf payloads with sequence management.
OPC-UA Bridge	Subscribes to OPC-UA server tags and republishes to the UNS.
Modbus TCP Bridge	Polls Modbus TCP registers and maps them to named tags.
Enterprise Gateway (SAP)	Bi-directional SAP ECC / S/4HANA connector via OData and RFC.
Enterprise Gateway (MES)	Unified MES connector supporting Ignition, SAP DM, Tulip, and others.
Action Logic Engine	NEW. Translates anomaly events and the Impact Array into machine commands.

2. The Unified Namespace (UNS)

The UNS is not a single block — it is the naming convention enforced by the UNS Builder across all T2 topics. Every MQTT message published by T2 follows this structure:

```
{Enterprise}/{Site}/{Area}/{Line}/{Cell}/{tagId}

Example:
  AcmeCorp/PlantA/Assembly/Line3/Station5/SpindleSpeed
```

The UNS Builder reads the assetContext injected by T1 Asset Registry to automatically construct this path. Engineers never manually type topic strings.

2.1 UNS Builder Configuration

1. Wire the T1 Asset Registry output (Port 1) to the UNS Builder input.
2. Set topicPattern to match your naming convention (default: {Enterprise}/{Site}/{Area}/{Line}/{Cell}/{tagId}).
3. Set defaultQos to 1 for most industrial applications (at-least-once delivery).
4. Enable retainBirth=true to send NBIRTH packets on broker reconnect (Sparkplug B requirement).

3. Protocol Bridge Configuration

3.1 MQTT Bridge (Sparkplug B)

This block both encodes outgoing telemetry as Sparkplug B NDATA Protobuf and decodes incoming Sparkplug B messages to plain JSON for downstream Node-RED nodes.

brokerHost	HiveMQ broker hostname or IP address
brokerPort	8883 for TLS (default), 1883 for plaintext
tlsEnabled	Set to true for production. Requires broker TLS certificate.
groupId	Sparkplug B group identifier (maps to ISA-95 Site or Area)
nodeId	Sparkplug B node identifier (maps to ISA-95 Equipment or Work Centre)
birthOnStart	Set to true to publish NBIRTH on Node-RED startup or reconnect

3.2 OPC-UA Bridge

Connects to an OPC-UA server and creates MonitoredItem subscriptions for configured node IDs. Change notifications are published to the UNS pipeline.

opcuaEndpoint	OPC-UA endpoint URL, e.g., opc.tcp://192.168.1.100:4840
subscriptionMode	subscribe (MonitoredItems, default) or poll (periodic read)
publishInterval	OPC-UA subscription publishing interval, e.g., 500ms
deadbandValue	Absolute deadband threshold — changes smaller than this are suppressed
sessionTimeout	OPC-UA session timeout in milliseconds (default 30000)

3.3 Modbus TCP Bridge

Reads Modbus TCP holding registers on a periodic poll cycle and converts raw register values to engineering units using a configurable register map.

host / port / unitId	Modbus TCP server address and unit ID (default port 502)
pollInterval	Polling frequency, e.g., 1000ms
registerMap	Path to a JSON file mapping register addresses to { tagName, eu, gain, offset }
scalingEnabled	Apply gain/offset formula: scaledValue = rawValue * gain + offset

Register map format:

```
[
  { "address": 0, "tagName": "SpindleSpeed", "eu": "rpm", "gain": 0.1,
"offset": 0 },
  { "address": 1, "tagName": "CoolantTemp",  "eu": "°C",  "gain": 1.0,
"offset": -40 }
]
```

4. Enterprise Gateways

4.1 SAP Gateway

Sends production confirmation records to SAP PP_PROD_CONF_SRV and receives work order data. Supports Basic Auth and OAuth2.

5. Set sapHost, systemId (e.g., PRD), and client (e.g., 100).
6. Set protocol to OData (default) or RFC for BAPI-based calls.
7. Set authType to basic and provide credentials, or use OAuth2 with a token endpoint.
8. Wire Port 2 to an error handler and Audit Logger for SAP fault visibility.

4.2 MES Gateway

Universal bidirectional MES connector. Set mesProvider to match your MES. Direction is controlled by msg.payload.direction = "inbound" or "outbound".

Outbound (OT → MES)	Report cycle completion, quality events, equipment alarms
Inbound (MES → OT)	Download active recipe, receive setpoints, get work order parameters

5. Action Logic Engine (Closed-Loop Control)

This is the most operationally critical block in the framework. It receives the Impact Array from the T1 Asset Graph and translates it into physical machine commands. Used correctly, it creates a fully automated closed-loop IIoT system.

5.1 How It Works

9. T3 Trend & Anomaly Detection detects an anomaly and emits an anomaly event.
10. The anomaly event flows to the Action Logic Engine input.
11. The ALE reads impactArray from the event — the list of affected ControlModule asset IDs.
12. For each assetId in impactArray, it looks up the matching rule in action-map.json.
13. It constructs a command object and publishes it to {unsTopic}/cmd.
14. An acknowledgement timeout starts. If no ACK arrives within ackTimeoutMs, Port 3 fires and a retry or escalation is triggered.

5.2 Action Map Configuration

Create /data/actions/action-map.json with rules per assetId and triggerType:

```
{
  "asset-uuid-station5": {
    "anomaly": {
      "type": "interlock",
      "command": "STOP",
      "defaultValue": 0
    },
    "threshold": {
      "type": "setpoint",
      "command": "SET_SP",
      "computeValue": "(triggerValue) => triggerValue * 0.9"
    }
  }
}
```

5.3 Safety — Dry Run Mode

Always test new action rules with dryRun=true first. In dry-run mode the block logs the command it would send without publishing to the MQTT command topic or writing Modbus registers.

6. Troubleshooting

Symptom	Cause	Check	Fix
Symptom	Likely Cause	Check	Fix
UNS Builder routes to Port 2	Missing assetContext in msg	T1 Asset Registry not upstream	Wire T1 Asset Registry → UNS Builder
Sparkplug B DEATH on startup	Broker TLS misconfiguration	Broker certificate and port	Set tlsEnabled correctly; use port 8883
OPC-UA Port 3 errors	Session timeout or endpoint unreachable	OPC-UA endpoint URL and network	Check opcuaEndpoint; increase sessionTimeout
Modbus scaling incorrect	Wrong gain/offset in register map	Register map JSON file	Recalculate gain/offset for each register
SAP Port 2 always fires	Auth or CSRF token missing	SAP authType and credentials	For OData, add X-CSRF-Token fetch before POST
Action Logic Engine no ACK	Device not responding to command topic	Subscribe to {unsTopic}/cmd	Verify device MQTT subscription and ACK logic