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P4NR OPC UA for NodeJS (English)

Understanding and Using OPC UA, node-opcua, and
Companion Specs with Node.js 24

Klaus Landsdorf

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node-opcua: The Handbook

Mastering OPC UA with TypeScript and Node.js

This book takes you from the fundamentals of the OPC UA specification, through the features of the open-source **node-opcua** stack, to a hands-on learning path with small examples for **Node.js 24**. It closes with a part on OPC UA NodeSets and Companion Specifications, each covered in its own chapter.

The manuscript is written in **Markua** and prepared for publication via [Leanpub](#).

A note on scope: The descriptions in this book refer to the node-opcua monorepo (meta-package node-opcua, feature status per supported_features.md in the repository). Commercial extensions (PubSub, the GDS runtime, and others) are clearly marked as such wherever they appear.

Preface

Imagine having to invent a new language for every project just to talk to a machine - and, on top of that, reinvent encryption, user management, and the data model each time. That was, for decades, the lived reality of automation: proprietary protocols, vendor-specific tag lists, spreadsheet mappings between a machine and the MES. **OPC UA** puts an end to this reinvention. It is the result of decades of work by hundreds of engineers from automation technology, IT security, and industry associations - captured in an open, vendor-neutral specification from the OPC Foundation, extended by **Companion Specifications** that standardize the vocabulary of entire industries (machine building, robotics, analytics, packaging, and more).

node-opcua makes this body of knowledge usable for the JavaScript/TypeScript world: a complete, MIT-licensed OPC UA stack for Node.js - client, server, discovery, security, and a rich Address Space, maintained by Sterfive and an active community around founder Etienne Rossignon. Anyone who builds on node-opcua isn't starting from a blank slate; they're building on years of industrially proven implementation work - and on the Companion Specs, which describe exactly what a machine, a robot, or an analytical device should look like in the Address Space, **so you don't have to design it yourself**.

That is the thread running through this whole book: **use existing knowledge instead of reinventing it**. This applies to people just as much as to AI-assisted tools that generate code against node-opcua or instantiate Companion Spec models - they, too, benefit from understanding the architecture, the terminology, and the node-opcua APIs instead of starting from zero every time.

Who is this book for?

- **Newcomers to OPC UA:** Part I takes you by the hand - with everyday analogies before every dry fact, before things get technical. You do not need to read the entire OPC 10000 spec series to get started.
- **Node.js/TypeScript developers** who want to build servers and clients with node-opcua: Parts II and III give you patterns to build from.

- **Experienced automation engineers and integrators** who use Companion Specs / NodeSets in practice and want a deeper understanding of *why* a given spec is built the way it is: Part IV deliberately goes beyond pure API usage and explains the technical motivation behind each spec, with references to the authoritative source.

New here? Read Parts I and III straight through, skim Part II as a reference, and pick only the Companion Specs from Part IV that are relevant to your industry. **Already experienced?** Jump straight to Part IV. Every chapter there is written to stand on its own: story, use cases, core concepts, node-opcua practice, sources.

How to read this book

1. **Part I** - an introduction to OPC UA (architecture, information model, services, security).
2. **Part II** - all relevant SDK features, anchored to concrete classes and packages.
3. **Part III** - a learning path with short Node.js 24 examples (ESM, node-opcua).
4. **Part IV** - NodeSets and Companion Specs: story, use cases, core concepts, node-opcua usage, and sources (the OPC UA Online Reference).

The code examples live per chapter under `manuscript/resources/examples/<chapter number>-<topic>/` and run as-is on Node.js 24. In the running text they are pulled in via Markua's code-include syntax (`<<[Title](Path)>`) - so the code you see printed is always exactly the file you run locally. That path describes the layout of the source manuscript Leanpub builds this book from - buying the finished book does not automatically hand you that folder. How to get the runnable examples yourself is explained in the "Setup for Node.js 24" chapter, in the "Downloading the examples" section.

Companion Specs are **taught and cited here, not replaced**: the authoritative texts remain with the [OPC Foundation Online Reference](#). See Appendix D (Bibliography).

Why teaching this is explicitly welcome: The OPC Foundation publishes the Companion Specs and their NodeSet2 files publicly, and node-opcua makes its catalog, XML, and TypeScript bindings available as open source - precisely so that users can understand, apply, and talk about them. This book explains publicly documented concepts, names, and architectural ideas, as well as how to work with public repository code; it never reproduces the full normative spec text anywhere. Every chapter in Part IV points explicitly to the authoritative source, so you can always find your way back to the original specification for binding details.

Conventions

- Code blocks are JavaScript/TypeScript for Node.js **24** (ES modules, `.mjs`, where it makes sense).
- Endpoint URLs follow the pattern `opc.tcp://hostname:port/path`.
- Markua asides (`A>`) mark tips and warnings.

Acknowledgments

Thanks go to Etienne Rossignon, Sterfive, and the node-opcua community for the stack, the documentation, and the Companion Spec integration. OPC UA and the Companion Specifications are works of the OPC Foundation and the respective working groups.

Part I: The OPC UA Specification

This content is not available in the sample book. The book can be purchased on Leanpub at <https://leanpub.com/p4nr-opcua-book-en>.

History, Goals, and Architecture

The story: why a whole new protocol?

In the 1990s, **OPC Classic** (OLE for Process Control) solved a real problem: Windows applications could access process data through a shared COM/DCOM interface, regardless of which vendor built the controller. That worked well - as long as everything was Windows, ran in the same network segment, and nobody had strict security requirements. With Industry 4.0, cloud connectivity, Linux devices, and tighter security requirements, that became a real problem: DCOM is firewall-hostile, tied to a single platform, and brings almost no built-in security.

The OPC Foundation could have tried to fix DCOM. Instead, it chose a fresh start with a clear goal: a protocol that runs on any platform (Windows, Linux, edge devices, the cloud), brings security along from the ground up, and carries not just values but their **meaning**. The result is **OPC Unified Architecture (OPC UA)** - not an update, but a complete redesign that has been under continuous development since the late 2000s.

The key point for you as a developer: these design decisions (firewall-friendliness, built-in security, semantic models) have already been made and are documented in the specification. You do not need to reinvent them - only understand them and apply them with a stack like node-opcua.

What is OPC UA?

OPC Unified Architecture (OPC UA) is a platform-independent specification for secure, semantically rich data exchange in automation. It replaces the older COM/DCOM-based “OPC Classic” and defines:

- an **information model** (objects, variables, methods, types, references),
- a **service set** (Browse, Read, Write, Subscribe, Call, History, ...),
- **security** (channels, certificates, user identities),

- optional **profiles** and **Companion Specs** for specific industries.

The OPC Foundation’s core series carries the numbers **OPC 10000-1** through **OPC 10000-x** (Parts). In practice, the parts on Concepts, the Security Model, Address Space, Services, and Profiles are enough to get started.

Why OPC UA?

Requirement	What OPC UA contributes
Firewall-friendly	A single TCP port, often 4840; no DCOM
Security	Signing, encryption, PKI, roles (Part 18)
Semantics	Typed address spaces, engineering units, alarms
Scalability	From nano devices to enterprise servers
Interoperability	Conformance units, Companion Specs, the CTT

Client/server and Pub/Sub

The classic model is **client/server**: the server holds the Address Space; clients browse, read, write, and subscribe.

Pub/Sub (Part 14) adds publish/subscribe messaging over UDP, MQTT, or Ethernet TSN - ideal for many receivers and deterministic networks. In the open-source `node-opcua`, PubSub is available as a **commercial module**; this book focuses on client/server.

Logical architecture

An OPC UA server exposes **endpoints**. Each endpoint describes a URL, a security policy, and a message security mode. The client:

1. discovers a server (via Discovery) or already knows the URL,

2. opens a **secure channel**,
3. creates a **session** (optionally with a user identity),
4. uses services (Browse, Read, Subscription, ...),
5. closes the session and the channel.

1 Client -- Secure Channel -- Session -- Services -- Address Space (Server)

Transport

The industrially dominant transport is:

- **UA-TCP + UA Secure Conversation + UA Binary** URL scheme:
`opc.tcp://...`

SOAP/HTTP/XML variants are specified but rarely relevant in practice or in `node-opcua`. A browser path over WebSocket (`opc.ws / opc.wss`) exists in the `node-opcua-client-browser` package.

Stacks and certification

A spec is only as good as its implementations. Stacks exist in C/C++, .NET, Java, Python, and - here - **TypeScript/Node.js** with `node-opcua`. The OPC Foundation verifies conformance with the **Compliance Test Tool (CTT)**. `node-opcua` provides Address Space and test helpers to support this.

The Information Model

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Node classes

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NodeId

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BrowseName, DisplayName, attributes

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References and hierarchy

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DataValue, Variant, StatusCode

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Events, Alarms & Conditions

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Historizing

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NodeSets and Companion Specs

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Services and Transport

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Discovery Service Set

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Secure Channel Service Set

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Session Service Set

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View Service Set

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Attribute Service Set

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Method Service Set

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MonitoredItem and Subscription Service Set

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Not supported, or commercial only

This content is not available in the sample book. The book can be purchased on Leanpub at <https://leanpub.com/p4nr-opcua-book-en>.

Encoding and chunking

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Security in OPC UA

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Three layers

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Message security mode

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Security policies (selection)

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Certificates and trust lists

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User identities

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Authorization and roles (Part 18)

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A practical checklist

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Part II: The node-opcua SDK

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SDK Overview

Why an SDK instead of implementing the spec directly?

The OPC UA specification describes encoding rules, cryptographic procedures, dozens of service messages, and a type system with inheritance - thousands of pages altogether. Any team that rebuilt all of this from scratch would spend months and repeat mistakes that other implementations have long since made and fixed. **node-opcua** encapsulates exactly this work: you write `session.read(...)` instead of hand-encoding binary messages.

What is node-opcua?

node-opcua is a complete OPC UA stack written in **TypeScript** for **Node.js** (and, experimentally, the browser). There is no native C++ binding: encoding, the secure channel, the Address Space, and services all run in JavaScript/TypeScript.

Property	Value
License (core)	MIT
Maintainer	Sterfive / community (originated by Etienne Rossignon)
npm facade	<code>node-opcua</code>
Architecture	Monorepo, 100+ packages
Homepage	http://node-opcua.github.io/

Installation

```
1 npm install node-opcua
```

For lean clients, this is often enough:

```
1 npm install node-opcua-client
```

Node.js version

For the examples in this book: **Node.js 24**. The upstream README typically states Node 20+; the monorepo itself is often built against newer engines. Node 24 is a future-proof choice for new projects.

A typical import

```
1 import {  
2   OPCUAServer,  
3   OPCUAClient,  
4   Variant,  
5   DataType,  
6   AttributeIds,  
7   nodesets,  
8   StatusCodes,  
9   MessageSecurityMode,  
10  SecurityPolicy  
11 } from "node-opcua";
```

Monorepo architecture

- **Facade** node-opcua - re-exports the public APIs.
- **Client** node-opcua-client - OPCUAClient, sessions, subscriptions.
- **Server** node-opcua-server - OPCUAServer, the engine, endpoints.
- **Address Space** node-opcua-address-space - modeling, events, history.
- **NodeSets** node-opcua-nodesets + node-opcua-nodeset-* - XML and types.
- **Security** certificate manager, secure channel, role sets.
- **Services** individual wire-message packages (node-opcua-service-read, ...).

Strengths

- Pure TS/JS - ideal for the cloud, edge devices, tooling, and fast iteration.
- Strong Companion Spec coverage.
- Production security policies, including Aes256.
- Open-source RBAC per Part 18.
- Extensive tests and industrial use.

Limits (open source)

- PubSub and the full GDS runtime: commercial.
- Node Management / Query services: not supported.
- Some legacy or niche profiles: incomplete.

Client Features

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OPCUAClient

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Session capabilities

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Subscriptions and monitored items

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User identity

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Discovery from the client

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Other client packages

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Server and Address Space

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OPCUAServer

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ServerEngine and Address Space

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Modeling API

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Loading NodeSets

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Diagnostics

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Lifecycle

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Subscriptions, Events, and Data Access

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DataChange subscriptions

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Event subscriptions

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Data Access in the SDK

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Extension objects and complex types

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Security, Certificates, and Configuration

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OPCUACertificateManager

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Security on client and server

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Server configuration / push certificates

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UserManager

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History, Alarms, and Methods

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Methods

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Historizing

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Alarms & Conditions

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File Transfer

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Discovery, File Transfer, and Role-Based Security

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Discovery and the LDS

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Role-based security (OPC 10000-18)

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Pseudo session

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Packages, Samples, and Extensions

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Important packages (short list)

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Samples in the repository

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Commercial / membership modules

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Feature matrix

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Part III: A Learning Path with Node.js 24

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Setup for Node.js 24

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Goal of this part

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Setting up a project

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Downloading the examples

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Learning order

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Example: A Mini Server

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Learning goal

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The full code

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Example: Client - Browse and Read

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Learning goal

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Common pitfalls

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Example: Subscription

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Parameters to experiment with

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Example: Methods

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Example: Data Access

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Example: Alarms

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Going further

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Example: History

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Learning goal

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Run it

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Client

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Example: Secure Access (UserName)

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Next steps toward production

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Part IV: OPC UA NodeSets and Companion Specs

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NodeSets and Companion Specs - Introduction

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What is a NodeSet?

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What is a Companion Spec?

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Finding your way around reference.opcfoundation.org

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Why teaching vs. licensing - a clarification

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The catalog in node-opcua

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Citation style in the sub-chapters

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The OPC UA Standard NodeSet (UA)

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Device Integration (DI) - OPC 10000-100

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Core concepts (selection)

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Dependencies

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Using node-opcua

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A teaching point: a typical mistake

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Analyzer Device Integration (ADI)

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A teaching point: a domain spec is not a replacement for DI

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AutoID - OPC 30010

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A teaching point: scan events, not polling

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Machine Vision - OPC 40100

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A teaching point: keep recipe and result thinking separate

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Commercial Kitchen Equipment - OPC 30200

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A teaching point: reuse energy and health fields from DI

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Asset Management Basics (AMB) - OPC 10000-110

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A teaching point: AMB is rarely loaded on its own

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The GDS Information Model - Part 12 /

GDS NodeSet

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Industrial Automation (IA) - OPC

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A teaching point: IA is invisible glue

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Machinery - OPC 40001-1

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A teaching point: AddIns

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Machinery Jobs - OPC 40001-3

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A teaching point: a formal dependency vs. a sensible overall architecture

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Machinery Result - OPC 40001-101

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A teaching point: recognize and reuse the generic pattern

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Machinery Process Values - OPC

40001-2

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A teaching point: semantics is not a nice-to-have

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Machine Tool - OPC 40501

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CNC - OPC 40502

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A teaching point: deliberately connect the CNC and Machine Tool views

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Robotics - OPC 40010

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Woodworking - OPC 40550

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A teaching point: a domain model inherits from Machinery, not the other way around

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Flat Glass - OPC 40301

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A teaching point: line integration, not just a single machine

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PackML - OPC 30050

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A teaching point: the state names are already agreed on - use them

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IO-Link and IO-Link IODD - OPC 30120

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IO-Link IODD

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A teaching point: keep process data and service data cleanly separated

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PADIM and IRDI - Semantics for Process Values

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A teaching point: IRDI is infrastructure, not an end in itself

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ISA-95 Job Control - OPC 10031-4

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A teaching point: base vocabulary, not a ready-made MES integration

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IJT Base and Tightening - OPC 40450 / 40451

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A teaching point: the longest dependency chain in the catalog is worth tracing

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LADS - OPC 30500

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A teaching point: recognize manufacturing patterns in the lab

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Metal Forming - OPC 40503

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A teaching point: the dependency graph is the real lesson here

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Scales / Weighing - OPC 40200

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A teaching point: handle legally-regulated weight values separately

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I4AAS - OPC UA and the Asset Administration Shell

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A teaching point: two communities, one model

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Using NodeSets in node-opcua in Practice

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A loading recipe (checklist)

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Pattern A - find a type and subtype it

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Pattern B - an instance in DeviceSet / Machines

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Pattern C - TypeScript bindings

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Pattern D - a client against a Companion Spec server

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Dependency graph (simplified)

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Example script in this book

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Conformance and reality

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Sources

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Appendix A: Leanpub and Markua

Notes

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Folder structure of this manuscript

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Markua conventions used in this book

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Release texts for the Leanpub book page

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Appendix B: Glossary

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Appendix C: Resources

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node-opcua

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OPC Foundation

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Leanpub / Markua

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A companion book

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Appendix D: Bibliography of Companion Specs

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node-opcua primary sources

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