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Enhancing TSN Configuration: A Hybrid CORECONF-NETCONF Approach for Constrained Devices

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Gefördert durch:

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Motivation

Why do we need new approaches to device configuration?

Challenge

- Ensuring reliable, scalable deployment methods across thousands of diverse, time-sensitive devices
- TSN (Time-Sensitive Networking) is essential, but configuration must keep pace with complexity

Industry 4.0 & Ethernetification

- Rapid increase in smart, connected devices
- **Ethernet** as the unified backbone for industrial connectivity
- Exponential growth drives configuration complexity

IT/OT Convergence

- **IT** systems integrating deeply with Operational Technology (**OT**)
- Examples: CNC machines, industrial robots, PLCs, sensors, actuators
- OT requires strict Quality of Service (**QoS**) and high reliability
- Heterogeneous networks: Diverse device capabilities, protocols, and requirements

Smart Factory Evolution

- Real-time data exchange between machines, systems, and sensors
- Automated workflows and adaptive manufacturing processes
- Interconnected devices require precise time synchronization and configuration
- Need for scalability and flexibility in device management to support continuous innovation

Configuration protocols

Short Overview

Common approaches to network configuration

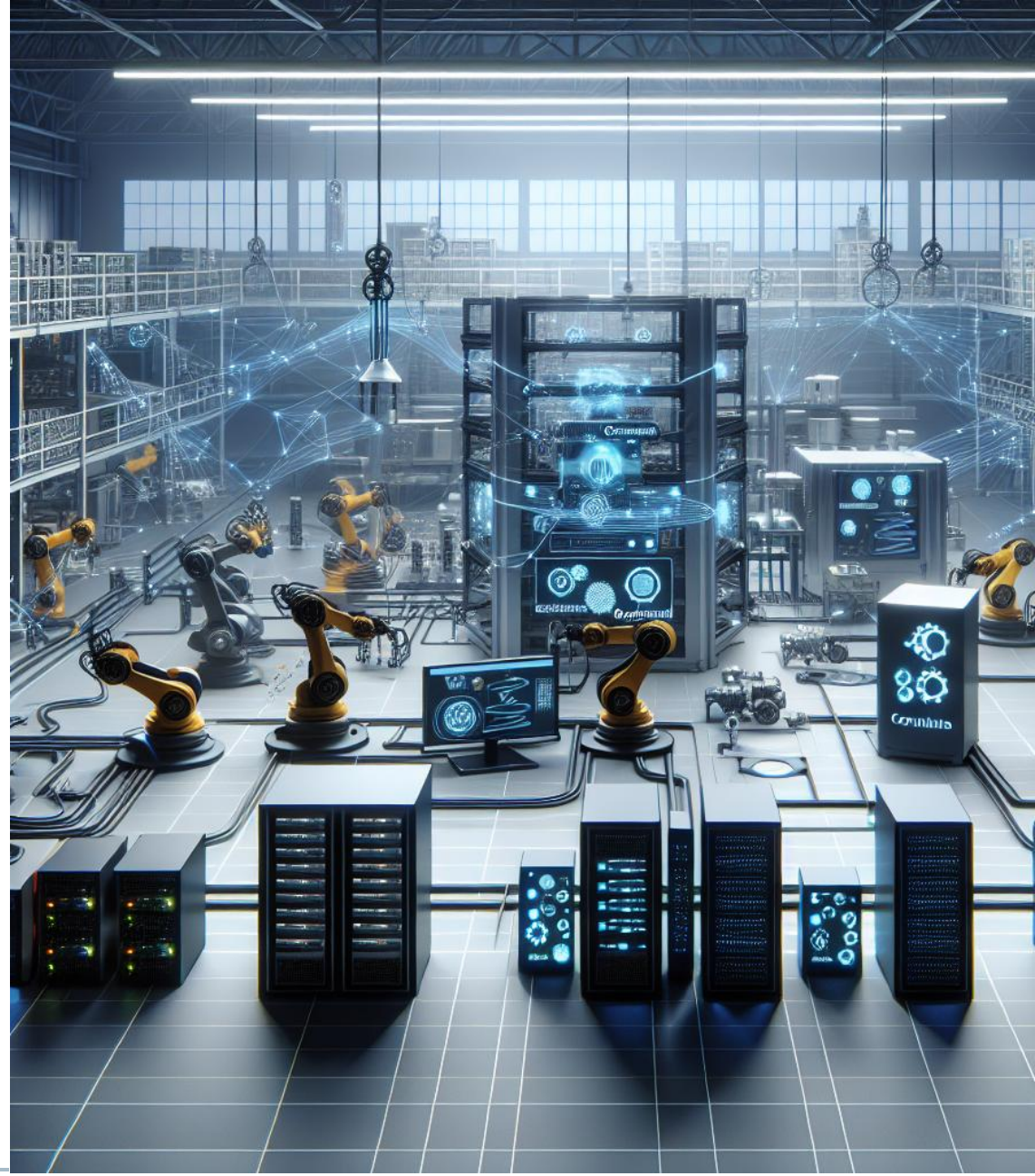
- current devices often use proprietary configuration protocols (CLI, REST)
- Simple Network Management Protocol (SNMP) was originally intended for network configuration purposes, but is only used for monitoring and status data
- SNMP lacks complexity and integrity
- Other missing features: atomic operations, transactional configuration, error handling

The Future speaks NETCONF/YANG

- A standard with strong traction in “feature-rich” devices, but not fully saturated in the market
  - YANG supports complex network modelling
  - NETCONF provides extended Protocol Features (e.g. candidates, error-options)

However…

- NETCONF (protocol operation, XML-parsing, …) is a heavy task demanding lots of ressources
- constrained devices are still often statically configured/need machine access for reconfiguration



Configuration protocols

CORECONF – CoAP Management InterfaceS

What is CORECONF?

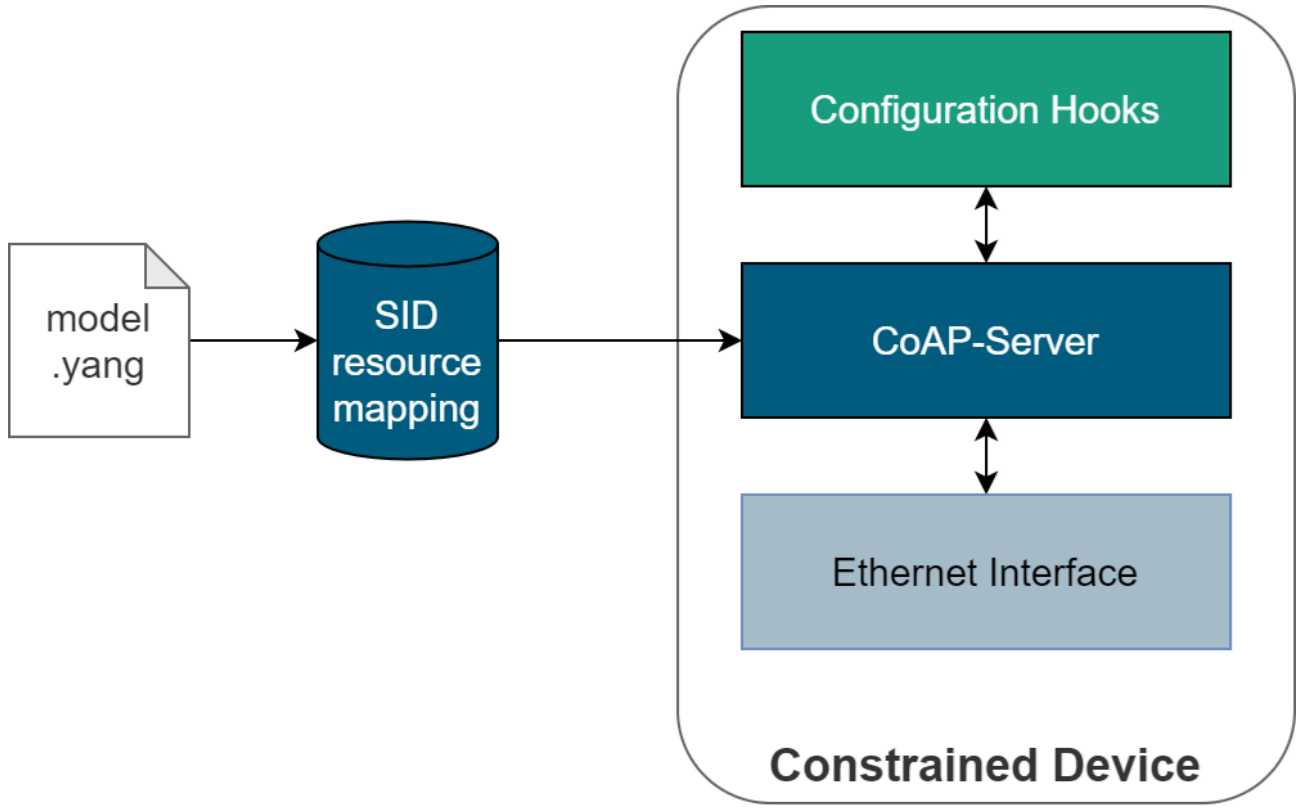
- REST-like interface via CoAP-Server
- YANG-based data model (SID - Schema Item iDentifiers)

General advantages

- CoAP is a well-defined RFC-Standard tailored to constrained environments
- CORECONF makes use of existing YANG models, same as NETCONF

Advantages for constrained devices

- Binary data representation (CBOR)
- Simple semantics for data access (GET, PUT, ...)
- MAY include datastores, but not required



IEC/IEEE 60802

TSN Profile for Industrial Automation

IEEE60802 "defines time-sensitive networking profiles for industrial automation. The profiles select **features, options, configurations, defaults, protocols, and procedures** of bridges, end stations, and LANs to build industrial automation networks."*

Device classification

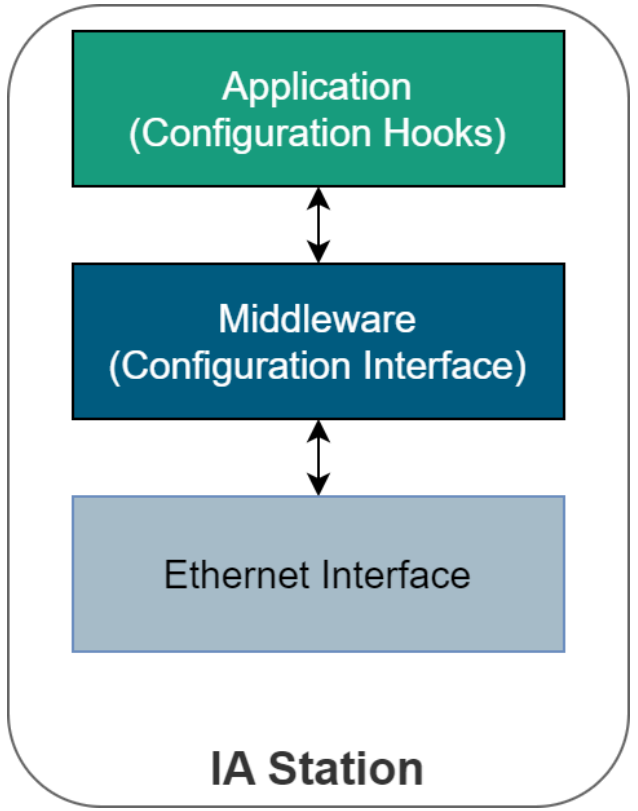
- Everything is an **IA-station**
- Conformance classes:
  - Feature rich **ccA**
    - e.g. PC, PLC
  - Constrained **ccB**
    - e.g. sensors, actors

IEEE60802 configuration

- Restricted to NETCONF/YANG or RESTCONF/YANG for ccA-devices

Recent draft 3.4

- Configuration of ccB IA-Stations (device interface, protocol) is **not specified**
- Introduction of management proxies



* Source: IEC/IEEE 60802 TSN Profile for Industrial Automation |

IEEE60802 Management Proxies

Working principle

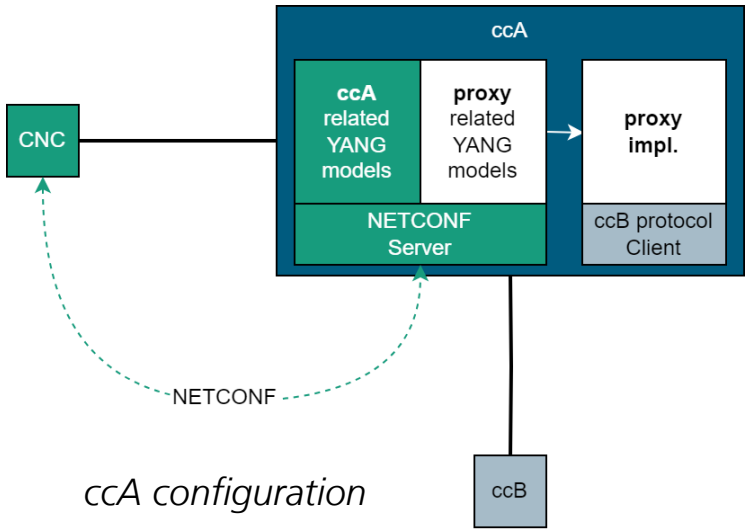
- Extension of IA-Station (ccA) bridges protocol gap for configuration of ccB Devices (acts as a translator)
- once discovered, constrained devices (ccBs) are assigned a proxy by the CNC (based on the proxies capabilities)
- The proxy accepts configuration requests for proxied clients via dedicated YANG models
- Proxy the requests to the desired protocol

Requirement

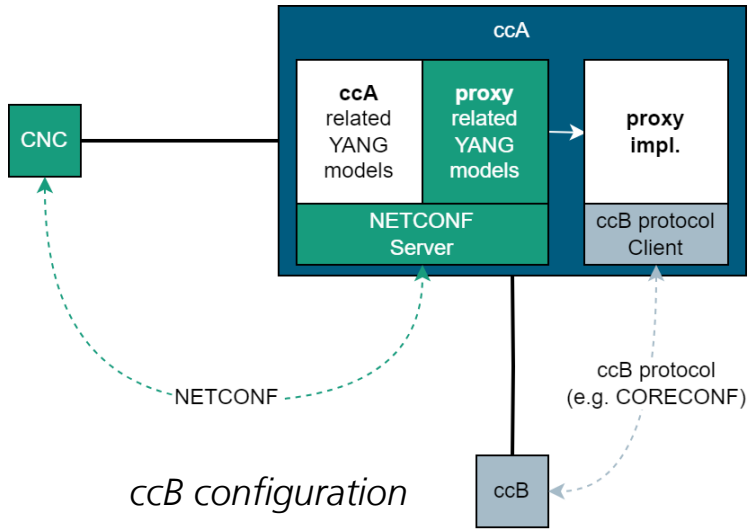
- ccBs protocol must be IP-based

Benefits

- CNC only needs to support NETCONF
- Resource-intensive protocol translation is performed on ccA device



ccA configuration



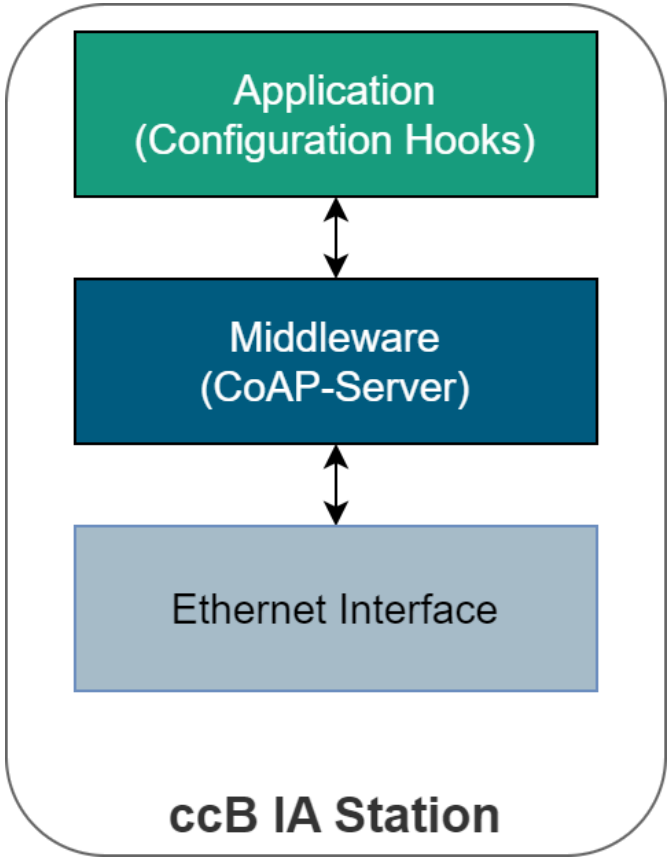
ccB configuration

IEEE60802 & CORECONF

Configuration protocol for constrained devices

Integration of CORECONF with NETCONF

- CORECONF seamlessly integrates with the IEEE60802 architecture
- Utilizing the Management Proxy functionality of IEEE60802
- YANG-based data modelling positions CORECONF as a strong candidate for the standard configuration protocol for ccB devices
- Still allows “standalone” management of a constrained („ccB“) device via CORECONF-CNC



Implementation of a CORECONF-Proxy

Challenge NETCONF / CORECONF Translation

- Ressource-heavy XML-parsing is done on the proxy side
- Constrained devices receive binary coded messages

But one NETCONF request can *simultaneously*:

- Access different YANG models and access different (hierarchical) layers in the same YANG model
- Combine different access modes/operations (replace, merge, delete, ...)
  - → Most NETCONF-requests cannot be mapped to a single CORECONF request

For Example:

- Semantic of some "operations" requires additional read operations in CORECONF
  - e.g. operation="delete" needs to raise an error if no configuration data exists for the resource
  - But a DELETE request in CORECONF always returns (2.02 Deleted) for a valid resources, even if it is empty

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Implementation of a CORECONF-Proxy

Challenge NETCONF request mapping

- “error-option” behaviour for <edit-config>-operation
  - CORECONF has no concept of error-options
  - Error-options need to be implemented on proxy side
- <get-config>
  - Shall return only configuration data
  - GET-Response needs to be filtered for relevant data

However, there is a gap:

- Management proxies are not only forwarding requests
- proxies needs to have a understanding of what‘s happening on the proxied device:
  - Process requests and responses
  - Check for changed configuration data
  - Handle error-options

→ The proxy needs to provide datastore access for each individual proxy-target

- **Accessing the specific data and models for a constrained device in the proxies datastore is currently undefined**

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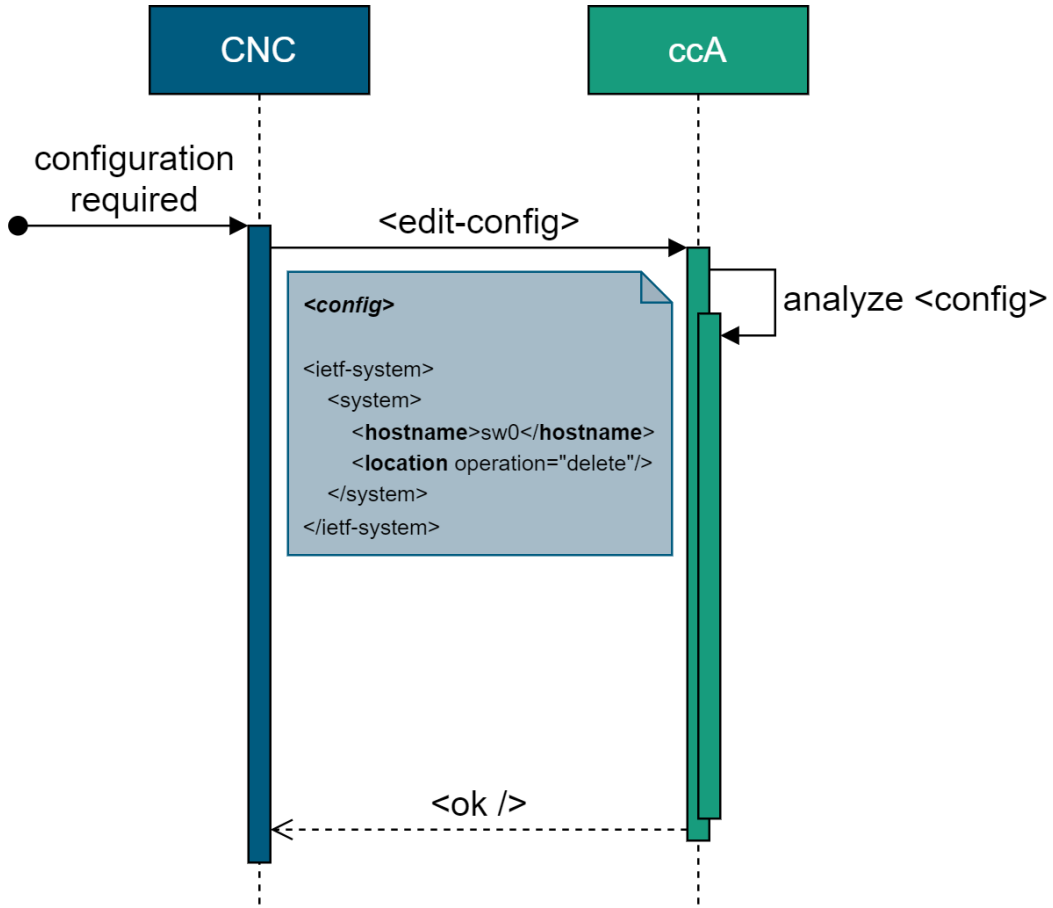
Implementation of a CORECONF-Proxy

Challenge NETCONF / CORECONF Translation



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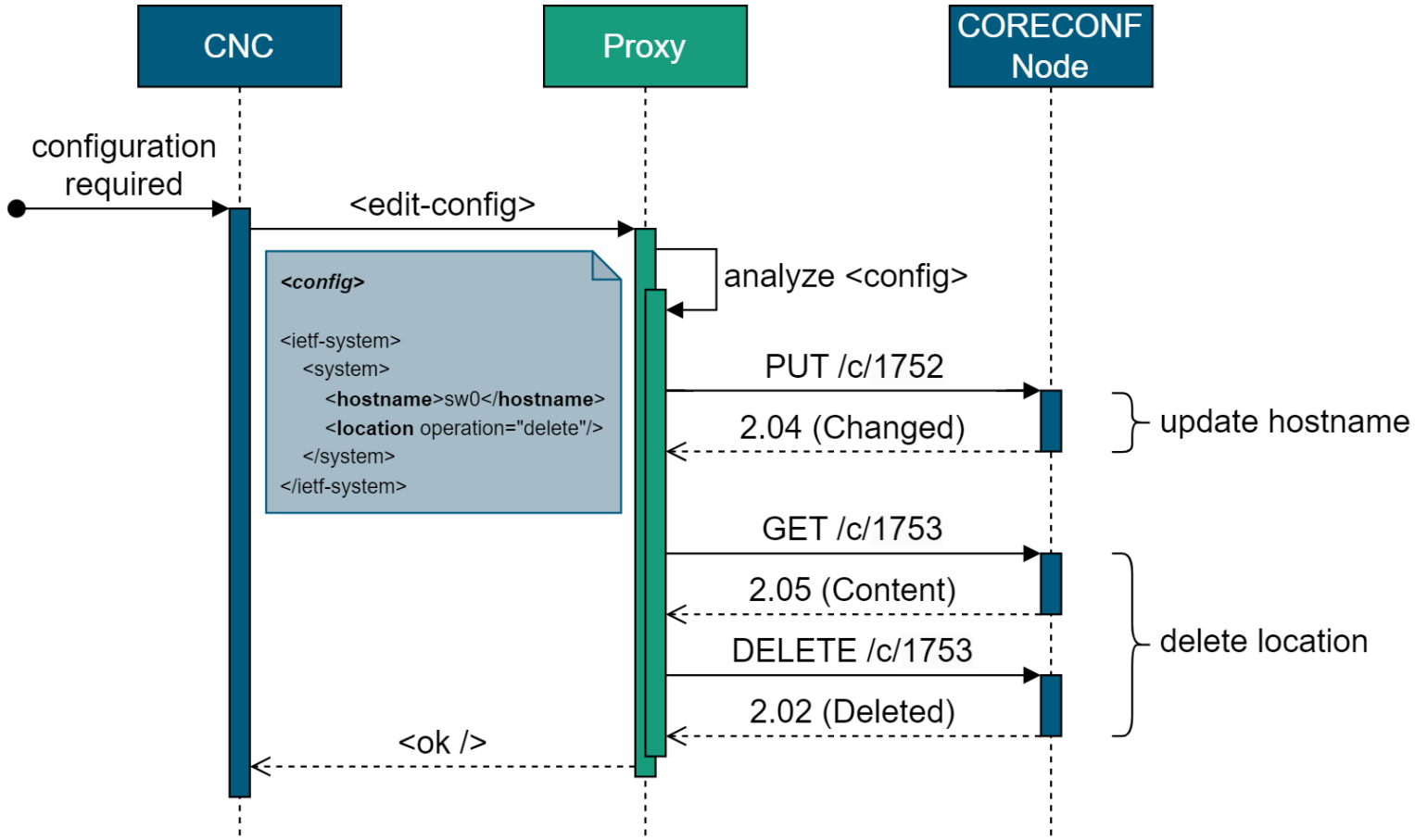
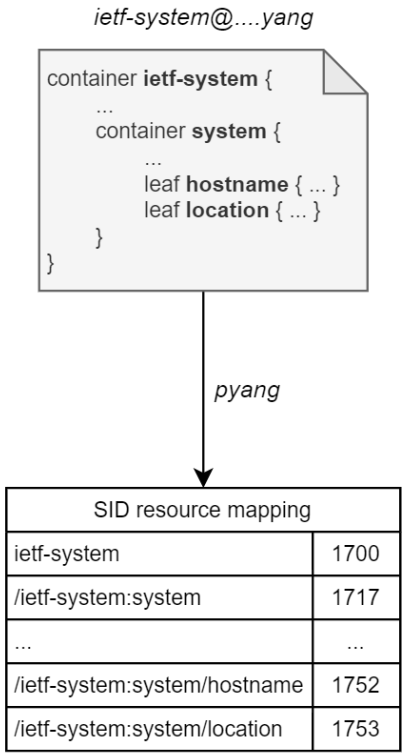
Implementation of a CORECONF-Proxy

Challenge NETCONF / CORECONF Translation





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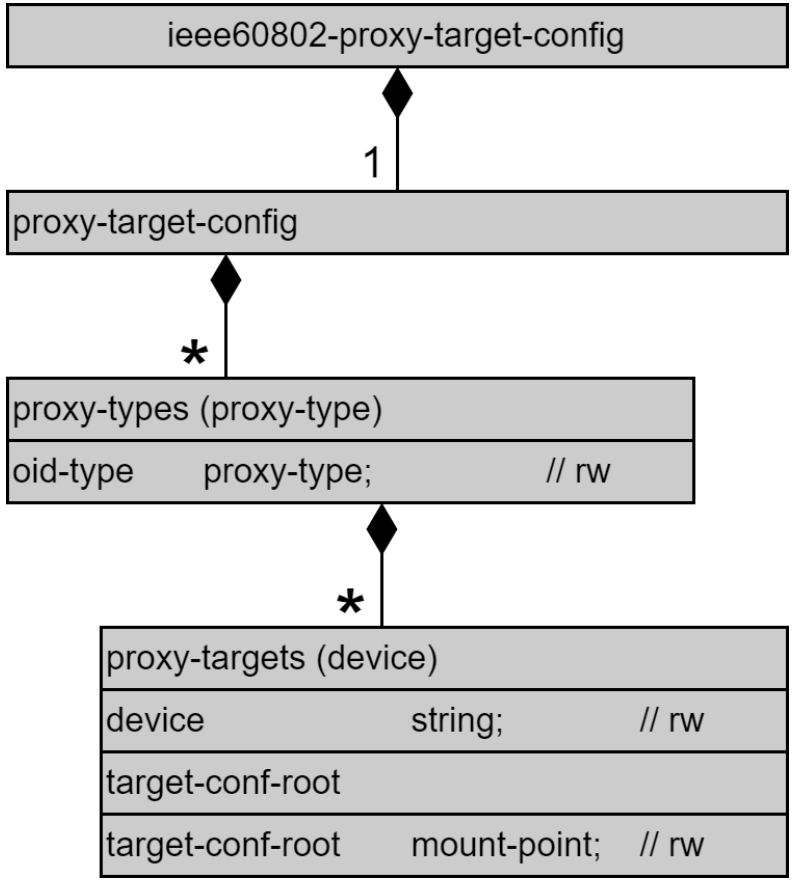
IEEE60802 Management Proxies

Proposal: iecieee60802-proxy-target-config

- Same nested list structure as in iecieee60802-proxy
- Configuration data for different proxy-targets stored in separate paths

```
module: iecieee60802-proxy-target-config
  +--rw proxy-target-config!
     +--rw proxy-types* [proxy-type]
        +--rw proxy-type          string
        +--rw proxy-targets* [device]
           +--rw device           string
           +--target-conf-root
              +--mp target-conf-root
```



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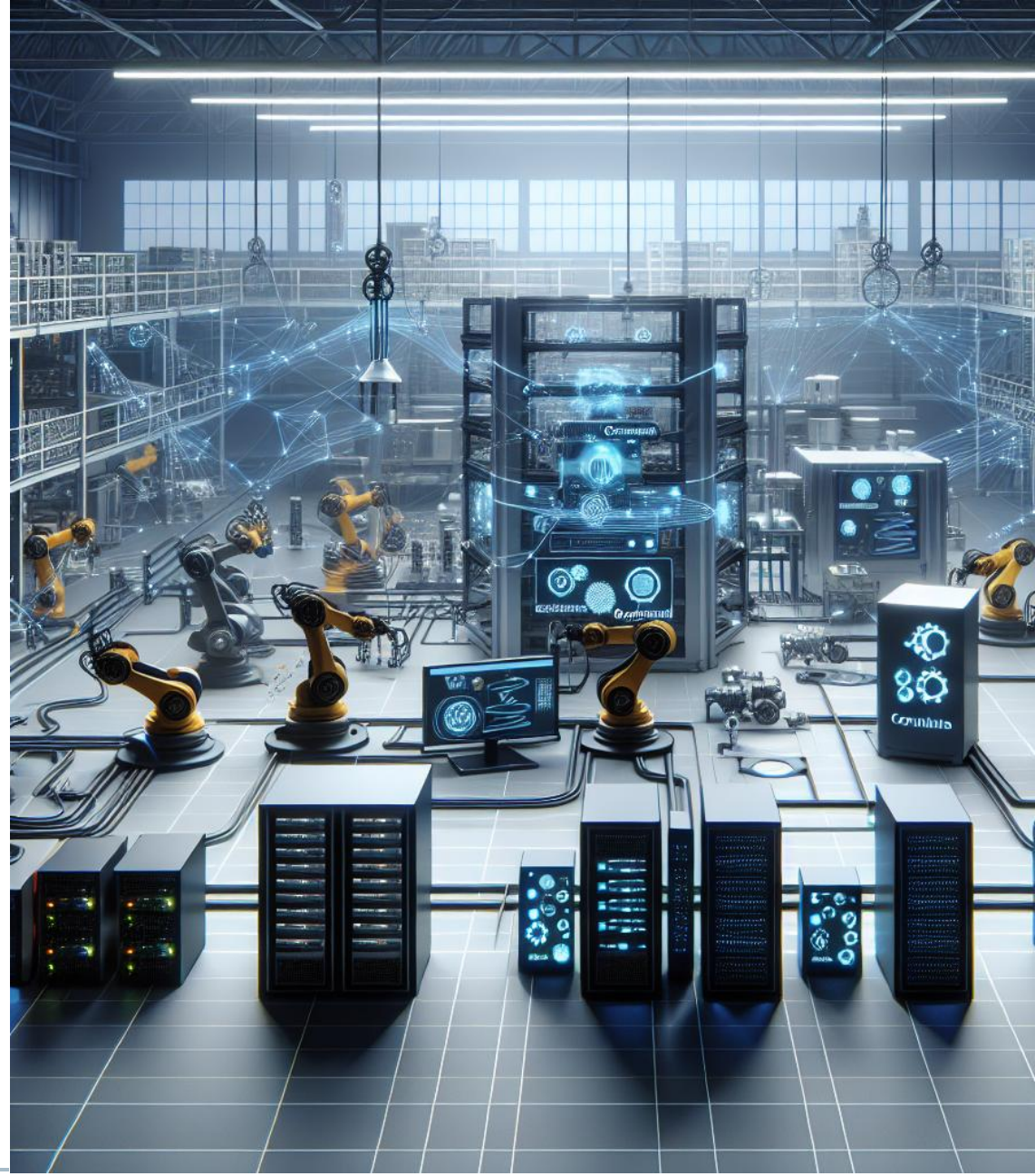
Conclusion + Outlook

Conclusion / Outlook

- **Configuration of constrained devices** remains a problem that requires a general solution
- **CORECONF** is a future-oriented protocol for ccB management
  - Based on the same data models as NETCONF
  - Simpler and less powerful access semantics, but can be well integrated with NETCONF
  - Even CORECONF has limitations

    → There will be devices that are not even capable of running a CORECONF server

- **IEEE60802 management proxies** are a good approach to configuration auf constrained devices
  - We propose an additional YANG model for proxied configuration to fill the knowledge gap on the proxy side



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Benchmarks

Ressource allocation

- Preliminary! Ressource utilization heavily depends on the installed/implemented YANG-models

- Embedded linux NETCONF (ROM / RAM Usage)
  - Libyang, sysrepo, libnetconf2, netopeer2 server: ~2200kB ROM
    - The true ressource utilization comes from linux dependencies like libssh, openssl, curl, IP-stack etc.
  - NETCONF Server (netopeer2-server): ~175MB RAM

- CoAP-Server + CBOR on RTOS:
  - 1950kB ROM / 2,5kB RAM Usage
  - Model implementation adds to ROM/RAM