Monitoring and Maintenance of Industry 4.0 Learning Laboratory using Digital Twin and Simultaneous OTA Updates

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Contents

Introduction

- Over The Air Updates – Wireless software/firmware updates in microcontroller units (MCU).
- Safety-Aware Over-The-Air (OTA) Updates for MCU has already been implemented in Industry 4.0 Learning Laboratory in ILM department. [1]
- Simultaneous OTA saves time and resources. It is extremely valuable in a dynamic factory layout.
- Digital Twin assists in monitoring and maintenance of factory layout

Aim of the Thesis

Provide a proof-of-concept for a Digital-Physical System Pair in the context of Smart Factories for remote monitoring of processes and providing wireless firmware updates.

State of the Art

- Arduino and Espressif provides bootloaders for OTA support.
- Latest Arduino boards contain OTA functionality – Arduino Cloud and Thinger cloud.
- Simultaneous OTA update is available by using softwares such as Mender and Thingsquare
- Digital Twin technology is mostly reserved to large automobile and communication industries.

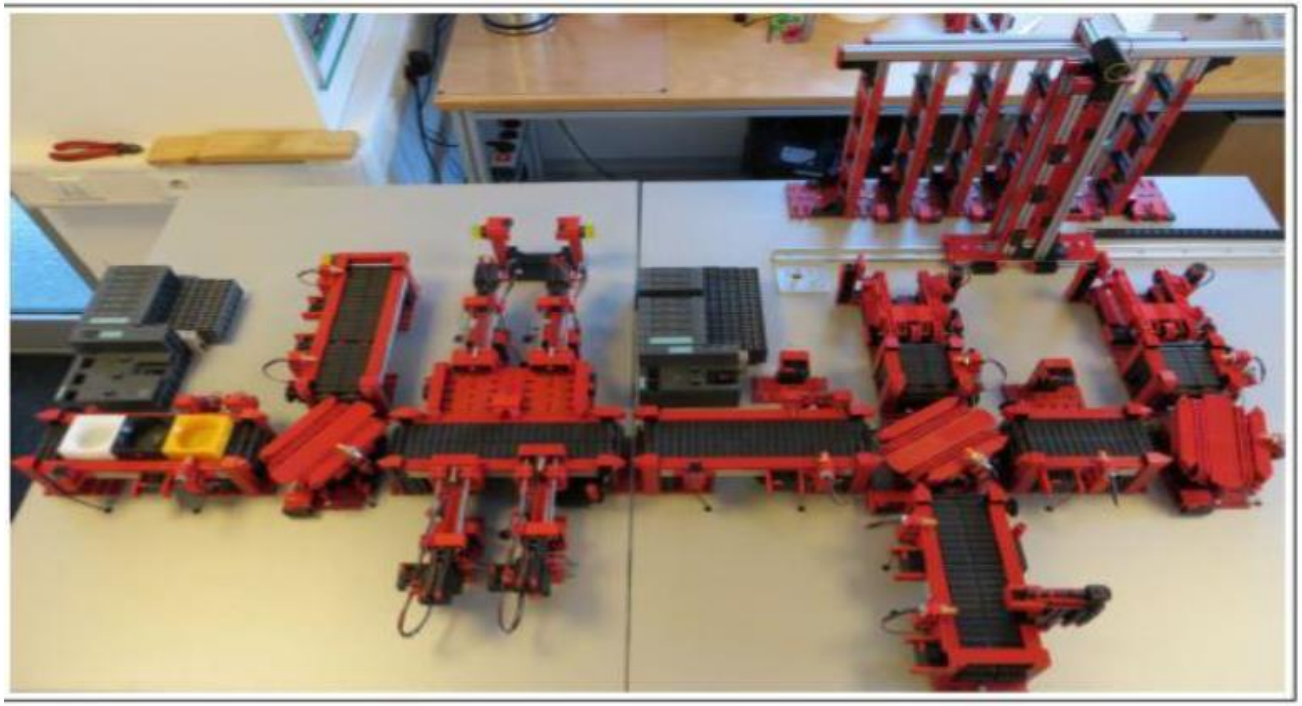
Literature Review

- Safety-Aware Over-The- Air Updates, A. Karri [1]
- Requirement Analysis for OTA Updates, J. Bauwens et. al. [2]
- OTA Security Issues, Challenges and Methods, S. Halder [3]
- Novel OTA Update Method, H. Guissouma [4]
- Dimensions of digital twin applications, Enders and Hoßbach [5]
- Digital Twins and Cyber-Physical Systems Tao et.al [6]
- The BASE MoVE research project, Akelbein et.al [7]

Motivation

- Standardized process for simultaneous OTA updates is not available.
- Multiple software solutions, each with its own limitations.
- Lack of a comprehensive demonstration of the monitoring, maintenance, and update of a factory layout.

Current State of the Industry 4.0 Learning Laboratory



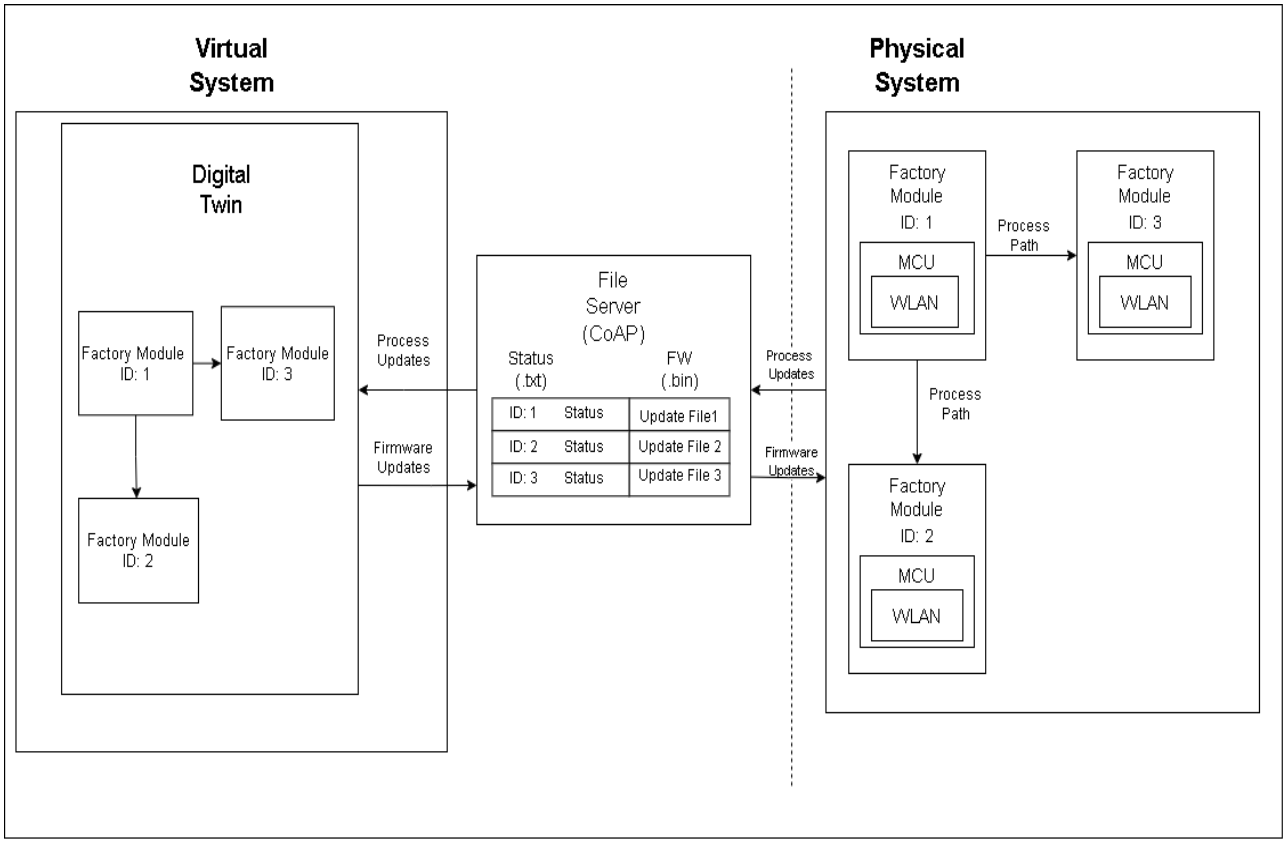
Unresolved Issues

- Processes in the physical factory needs to be detected remotely.
- Consequent change in the control logic must be uploaded to the factory modules.

Proposed Methods and Experiments

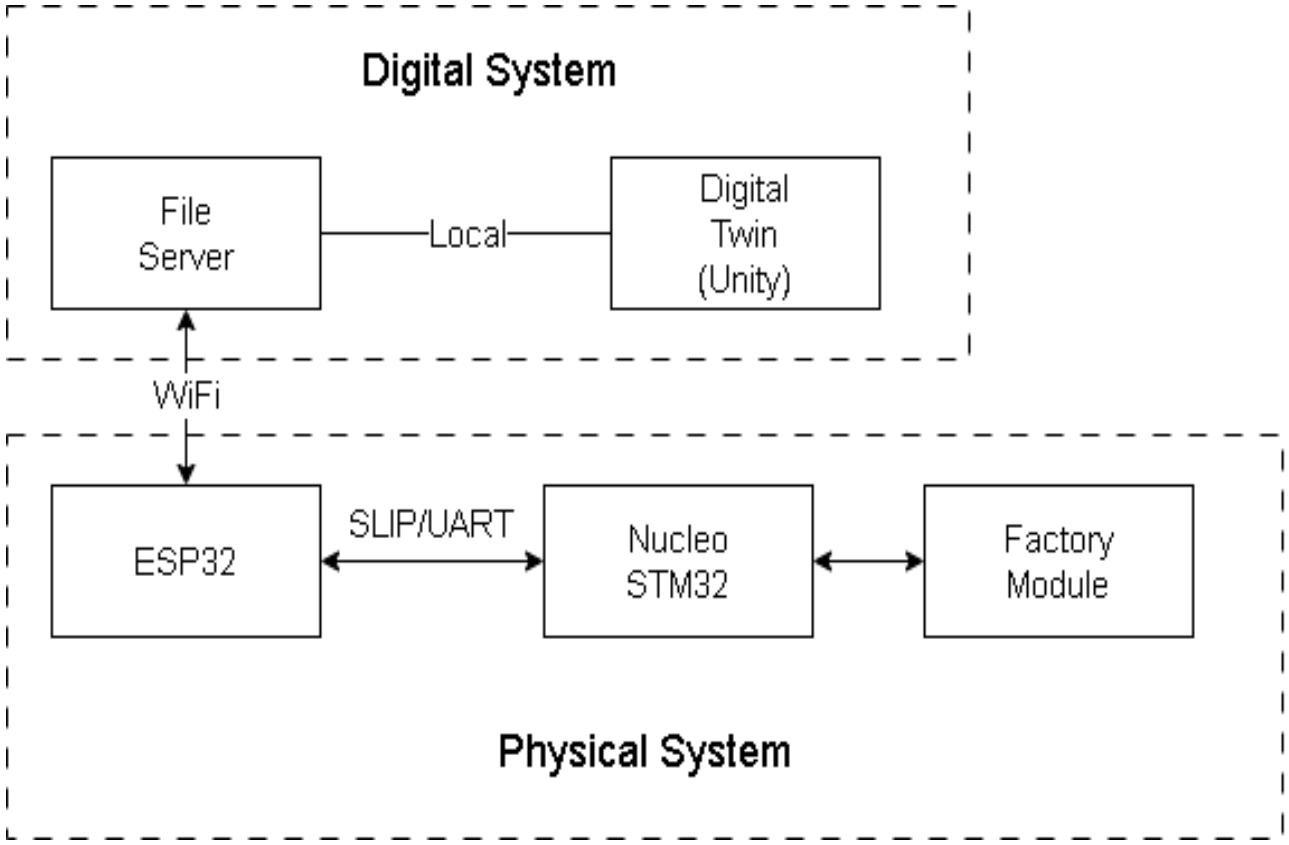
- Extension of RIOT architecture to all modules.
- **Monitoring**: Development of Digital Twin.
- Experimentation with multiple factory layouts.
- **Update**: Interface added in the digital twin to provide OTA firmware updates.
- Measurement of OTA update success rate.
- **Maintenance**: Measurement of Machine Downtime.

Concept Diagram

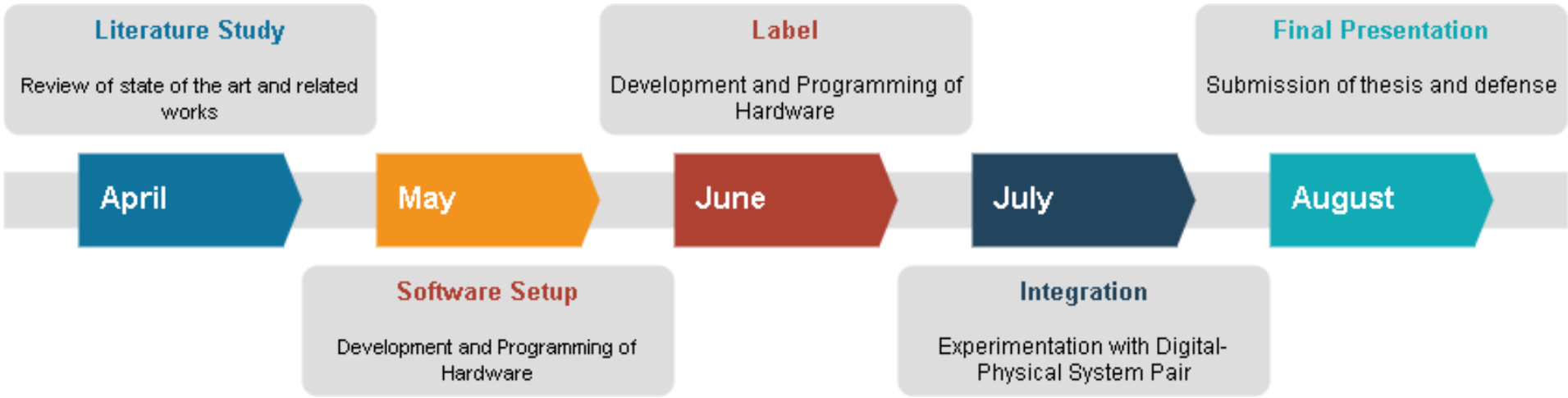


- The diagram shows a sample layout which is replicated in the digital twin.
- The consequent changes made in the program routine are updated over the air.

Development Goals



Estimated Timeline



Summary

- Industry 4.0 Learning laboratory is utilized for experimentation.
- Existing architecture of the factory modules is extended to create a well-connected “smart factory” in the laboratory.
- Multiple factory modules with different program routines are simultaneously updated over the air, based on several layouts.
- Digital Twin is developed and functionality is added for handling multiple OTA updates.
- Success rate of OTA update and machine downtime is measured.

References

[1] Karri, A. Development and Evaluation of Safety-Aware Over-the-Air (OTA) Updates in the Factory Planning Laboratory. Otto-von-Guericke University, 2021.

[2] J. Bauwens, P. Ruckebusch, S. Giannoulis, I. Moerman und E. De Poorter. Over-the-Air Software Updates in the Internet of Things: An Overview of Key Principles. IEEE Communications Magazine, Vol. 58:35-41, 2020

[3] S. Halder, A. Ghosal und M. Conti. Secure Over-The-Air Software Updates in Connected Vehicles: A Survey. Computer Networks, Vol. 178:107343, 2020

[4] H. Guissouma, C. P. Hohl, H. Stoll und E. Sax. Variability-Aware Process Extension for Updating Cyber Physical Systems Over the Air. In: 2020 9th Mediterranean Conference on Embedded Computing (MECO), 2020, pp. 1-8

[5] M. R. Enders und N. Hoßbach. Dimensions of digital twin applications-a literature review. 2019

[6] F. Tao, Q. Qi, L. Wang und A. Nee. Digital twins and cyber-physical systems toward smart manufacturing and industry 4.0: Correlation and comparison. Engineering, Vol. 5(4):653-661, 2019.

[7] Akelbein, J. P., Beckmann, K., Hoss, M., Schneider, S., Seyfarth, S., & Thoss, M. (2021). BASE MoVE-A Basis for a Future-proof IoT Sensor. INFORMATIK 2020.

Thank You!