

FH Aachen

Faculty

Electrical engineering and information technology

Bachelor Thesis

**Design and Implementation of a Performance Measurement System
for an Industrial Sewing Machine**

Nicolas Harrje

Matr.-Nr.: 3518047

Referent: Prof. Dr-Ing. ...

Korreferent: Prof. Dr-Ing. ...

July 2, 2025

Erklärung

Ich versichere hiermit, dass ich die vorliegende Arbeit selbstständig verfasst und keine anderen als die im Literaturverzeichnis angegebenen Quellen benutzt habe.

Stellen, die wörtlich oder sinngemäß aus veröffentlichten oder noch nicht veröffentlichten Quellen entnommen sind, sind als solche kenntlich gemacht.

Die Zeichnungen oder Abbildungen in dieser Arbeit sind von mir selbst erstellt worden oder mit einem entsprechenden Quellennachweis versehen.

Diese Arbeit ist in gleicher oder ähnlicher Form noch bei keiner anderen Prüfungsbehörde eingereicht worden.

Aachen, July 2, 2025

Geheimhaltung - Sperrvermerk

Die vorliegende Arbeit unterliegt bis [Datum] der Geheimhaltung. Sie darf vorher weder vollständig noch auszugsweise ohne schriftliche Zustimmung des Autors, des betreuenden Referenten bzw. der Firma [Firmenname und -sitz] vervielfältigt, veröffentlicht oder Dritten zugänglich gemacht werden.

Contents

1. Introduction	4
1.1. Motivation und Aufgabenstellung.....	4
1.2. Vorgehensweise	5
2. Foundations	6
2.1. Definitions.....	6
2.1.1. IoT and IIoT	6
2.2. State of the Art	6
2.2.1. Industrial IoT Architectures and Patterns	6
2.2.2. Performance measurement in production environments	8
2.2.3. IoT-Plattformen	8
2.2.4. Databases	8
2.2.5. Dashboarding.....	8
3. Kapitel 3	9
4. Zusammenfassung und Ausblick	10
Quellenverzeichnis	11
Abkürzungsverzeichnis	12
Abbildungsverzeichnis	13
Tabellenverzeichnis	14
Anhang	14
A. Quellcode	15
B. Rohdatenvisualisierungen	16

1. Introduction

1.1. Motivation und Aufgabenstellung

1.2. Vorgehensweise

2. Foundations

2.1. Definitions

2.1.1. IoT and IIoT

The term Internet of Things was first coined by [Ashton,] when explaining the idea of combining RFID with the internet in an executive meeting. He explains that on the "normal" internet, most of the content is created by human beings. In contrast to this in the Internet of Things the data is generated by things and often describes things. But his emphasizes lays more on the description of things. For example to track and count them. The information to do so would come from sensors and RFID, he says. Of course in these days more of the information on the internet is generated by bots and AI. But other than that the distinction still holds true.

The Internet Society [Rose et al.,] further explains that in the Internet of Things, machines are communicating with each other and are addressable via an own IP address. This standardizes the way in which devices communicate. They also mention that "Today, the Internet of Things has become a popular term for describing scenarios in which Internet connectivity and computing capability extend to a variety of objects, devices, sensors, and everyday items."

The Industrial Internet of Things is just the description of a domain where the IoT is used. In this case in manufacturing. [Wha,]

2.2. State of the Art

2.2.1. Industrial IoT Architectures and Patterns

Due to the requirement that the solution be developed utilizing IoT technologies and is set within a production context, a review of Industrial IoT (IIoT) architectures and patterns was conducted. The Industrial Internet Reference Architecture (IIRA) [?] serves as a comprehensive framework, offering valuable insights into various architectural models and design patterns relevant to this domain. This reference architecture describes the following patterns: IoT Component Capability Pattern, Three-Tier Architecture Pattern, Gateway-Mediated Edge Connectivity and Management architecture pattern, Digital Twin Core as a Middleware Architecture Pattern, Layered Databus Architecture Pattern, System-of-Systems Orchestrator Architecture Pattern. Of these patterns only the first two are applicable within the scope of this work. Therefore the other ones will only be described on the surface.

Architecture Patterns IoT architecture patterns define the structure and operation of various IoT systems, detailing their implementation and highlighting their unique characteristics.

IoT Component Capability Model Pattern A single component and its associated capabilities are described, with the possibility that a component may comprise multiple sub-components. Consequently, the entire system can also be regarded as a component. The specific meanings of the capabilities are illustrated in the accompanying figure.

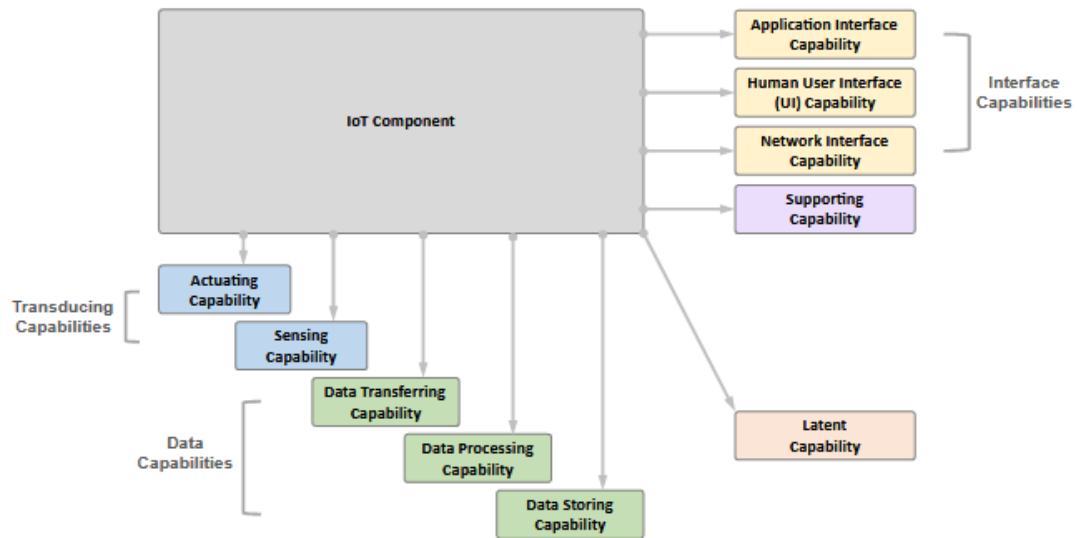


Figure 2.1.: Component Capability Pattern.

Three-Tier Architecture Pattern The system comprises the Edge, Platform, and Enterprise Tiers, as well as connecting networks. The Edge Tier contains sensors and gateways that collect data. These are connected by the Proximity Network. Data preprocessing may already be happening there.

The Platform Tier is responsible for most data processing and storage via databases. It is connected to the Edge Tier via the Access Network.

The Enterprise Tier provides domain-specific applications and interfaces for end users. These are built upon the processed data from the platform tier. It also issues controls to lower tiers. This tier is connected to the Access Network via the Service Network. The three tiers can also be further divided into different domains. That makes sense for bigger systems. But for a simple system as the one described in this work it is not necessary and therefore these domains will be explained here.

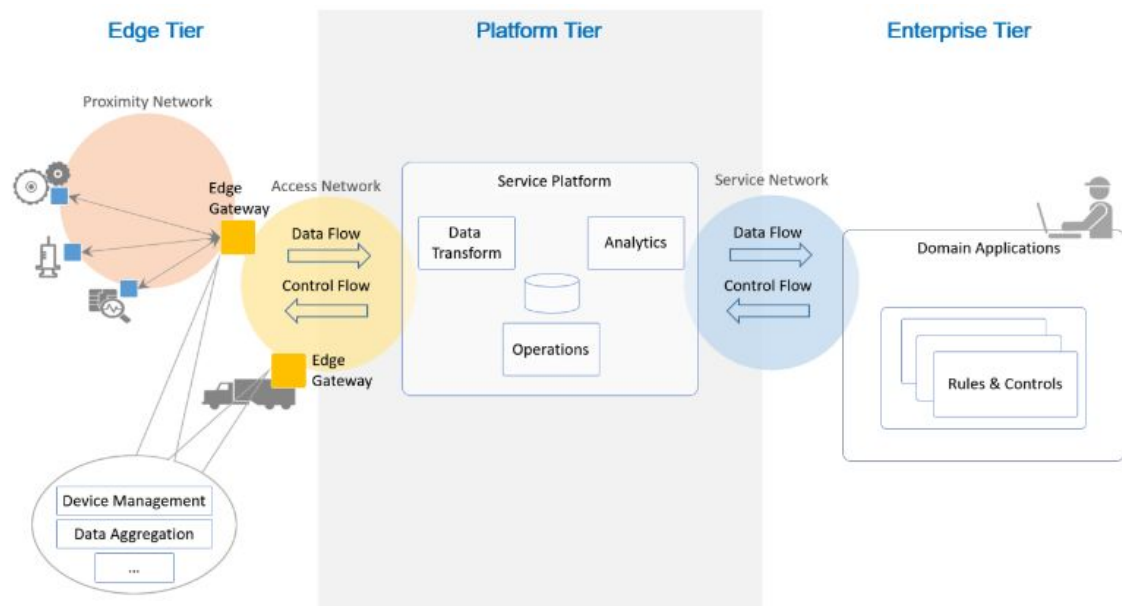


Figure 2.2.: Three Tier Architecture

2.2.2. Performance measurement in production environments

Key Performance Indicators The team around [Kang et al., 2016] from the National Institute of Standards and Technologie in the U.S. has worked out the different kinds of KPI's that are being used in operation management and production and how the various metrics and KPI's are related to each other.

First there are the supporting elements which in this thesis will be called metrics because they describe the measured data that is needed to calculate the basic KPI's. The supporting elements are devided into the categories time and quantity.

Then there are maintenance elements which give insight into upkeep of the machines. Of which the following were able to be calculated with the given metrics.

2.2.3. IoT-Plattformen

2.2.4. Databases

2.2.5. Dashboarding

3. Kapitel 3

Table 3.1.: Messergebnisse

Stellung	$\frac{T_U}{^{\circ}C}$	$\frac{T_c}{^{\circ}C}$	$\frac{\Delta T}{^{\circ}C}$
senkrecht (0°)	27,3	69,8	42,5
waagrecht (90°)	26,6	70,6	44,0

Table 3.2.: Smartphone Sensordaten

Sensorinformation	Format	frequency [s^{-1}]
App identifier for vendor	int64	once per transfer
WIFI and network carrier IP addresses	int128	once per transfer
battery level	int8	0.1
Position information: latitude, longitude, altitude, speed, course, vertical position accuracy, horizontal position accuracy, floor level information	float32[8]	1
Heading information: heading.x, heading.y, heading.z, true heading, magnetic heading, heading accuracy	float16[6]	1
Accelerometer information: acceleration.x, acceleration.y, acceleration.z	float16[3]	2
Gyroscope information: rotationRate.x, rotationRate.y, rotationRate.z	float16[3]	2
altimeter information: relative altitude, pressure	float16[2]	1
timestamp	uint32	once per transfer
Temperature [$^{\circ}C$]	float16	1

Wie in Tabelle 3.2 zu sehen ist, ist es besser, Trennlinien nur dort einzusetzen, wo logische Grenzen liegen.

4. Zusammenfassung und Ausblick

Bibliography

[Wha,] What is IoT (Internet of Things)? | Definition from TechTarget.
<https://www.techtarget.com/iotagenda/definition/Internet-of-Things-IoT>.

[Ashton,] Ashton, K. That 'Internet of Things' Thing.

[Kang et al., 2016] Kang, N., Zhao, C., Li, J., and Horst, J. A. (2016). A Hierarchical structure of key performance indicators for operation management and continuous improvement in production systems. *International journal of production research*, 54(21):6333–6350.

[Rose et al.,] Rose, K., Eldridge, S., and Chapin, L. The Internet of Things: An Overview.

Abkürzungsverzeichnis

<i>IoT</i>	Internet of Things
<i>IIoT</i>	Industrial Internet of Things
<i>KPI</i>	Key Performance Indicator

List of Figures

2.1. Component Capability Pattern.....	7
2.2. Three Tier Architecture	8

List of Tables

3.1. Messergebnisse	9
3.2. Smartphone Sensordaten	9

A. Quellcode

1. Source 1
2. Source 2

B. Rohdatenvisualisierungen

1. Graustufen
2. Verteilungen