

# INTERNET OF THINGS

## Introduction



Prof. Dr. Oliver Hahm

2024-10-21

# AGENDA

- About
- Organizational
- Introduction
- Research Fields

# ABOUT

# PROF. DR. OLIVER HAHM



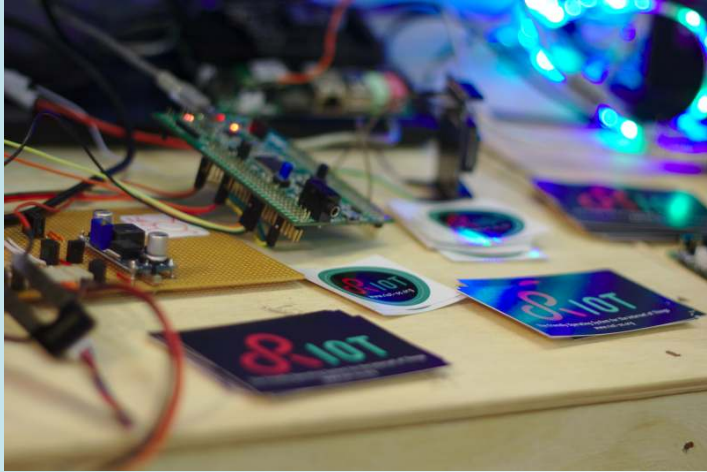
- Study of Computer Science at Freie Universität Berlin
- Software Developer for ScatterWeb and Zühlke Engineering
- Research on IoT and Operating Systems

## CONTACT

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**Appointments:** via e-mail, room 1-212

# JOIN THE RIOT!



*RIOT is the friendly operating system for the IoT!*

You're interested in ...

- ...programming the IoT?
- ...collaborate with hundreds of people from all over the world?
- ...contribute to a big FLOSS project?

Get in touch and do some hacking at the *All RIOT* event at the university! Usually every second Wednesday at 2pm in room 1-237.

Or look at <https://allriot.dahahm.de>



# ORGANIZATIONAL

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- This seminar is for students of *Allgemeine Informatik* only
  - There are separate seminars for students of *High Integrity Systems (HIS)*
- It takes place as a face-to-face course, i.e., participation is mandatory
- All course material can be found at  
[https://teaching.dahahm.de/teaching/iot\\_ws24.html](https://teaching.dahahm.de/teaching/iot_ws24.html)



# LEARNING OBJECTIVES

- Comprehension of IoT systems
  - understand the basic technologies for the Internet of Things,
  - assess emerging technologies concerning their suitability,
  - get acquainted quickly with new technologies, and
  - develop new application fields.
- Scientific skills
  - to search for, read, summarize and cite scientific literature on a large scale;
  - to read and interpret national and international standards;
  - to write a report as a scientific paper;
  - to give a scientific talk.



# ORGANIZATIONAL

- Individual work
- Each student selects a research field from a given list
- Get an overview about the selected field
- Present this overview to the rest of the course
- Identify a relevant research question in this field
- Submit a report in the end
- Summarize a randomly selected topic

## Hands-on Experience

In order to gain a solid understanding of IoT technologies, it is inevitable to gather practical experience: Four times this semester we will conduct some hands-on sessions.

# CAMPUAS



Enrolment Key:

[HahmIoT](#)

# THE GOALS

- This is a seminar: we won't get very far without your commitment and your contribution
- Everyone (including myself) should learn something
- Presentations should give an introduction and high level overview
- Report should dig into one particular research problem within the area

# FORMAT AND SCOPE

- Presentations:
  - General introduction into the topic
  - Should not exceed 25 minutes
  - Presentation tool of your choice
- Report:
  - Four pages (including references)
  - IEEE double column format<sup>1</sup>
  - LaTeX or Microsoft Word
  - Submission via campUAS
- Summary:
  - Half a page
  - Topic will be assigned at the end
  - Submission via campUAS

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1. <https://www.ieee.org/conferences/publishing/templates.html>

# DATES

- **October 21, 2024:** Introduction
- **October 28, 2024:** Research field selection and introduction into scientific work
- **November 04, 2024:** First Hands-on Session (Getting to know RIOT)
- **December 02, 2024:** Second Hands-on Session (Connecting *things* to the Internet)
- **January 06, 2025:** Third Hands-on Session (Setting up the cloud services)
- **February 03, 2025:** Last Hands-on Session (Connecting the dots)
- **February 14, 2025:** Report submission
- **February, 21, 2025:** Summary submission

In between:  
your presentations

# ASSESSMENT



- 30% for the report
  - Content
  - Structure
  - Presentation and format
  - Literature
- 20% practical work
- 40% for the presentation
- 10% summary on a randomly selected topic

# PLAGIARISM AND GENERATIVE AI

## Plagiarism won't be tolerated

- **Generative AI** can be useful...
- ...but won't provide the content/knowledge

# GRADING SYSTEM

## Definition of the Grades

- **1.0**  
An excellence performance. It is awarded if the work evaluated is outstanding, flawless and near perfection. It exceeds the expectations and is particularly witty.
- **2.0**  
A good performance. The work evaluated meets the expectations and fulfills the requirements well. It may contain some minor or formal errors.
- **3.0**  
A satisfying performance. The work evaluated meets most of the expectations and fulfills the basic requirements. It contains some clear errors that should be corrected.
- **4.0**  
A sufficient performance to pass the examination. The work evaluated fulfills the bare minimum but significantly more. It contains several clear errors that must be corrected.
- **5.0**  
An insufficient performance. The work evaluated does not even fulfill the basic requirements and is not enough to pass the exam. It may also be awarded in case of cheating or plagiarism.

# FURTHER INFORMATION

All material regarding this course can be found at  
<https://teaching.dahahm.de>

This includes

- Announcements
- Slides
- Dates



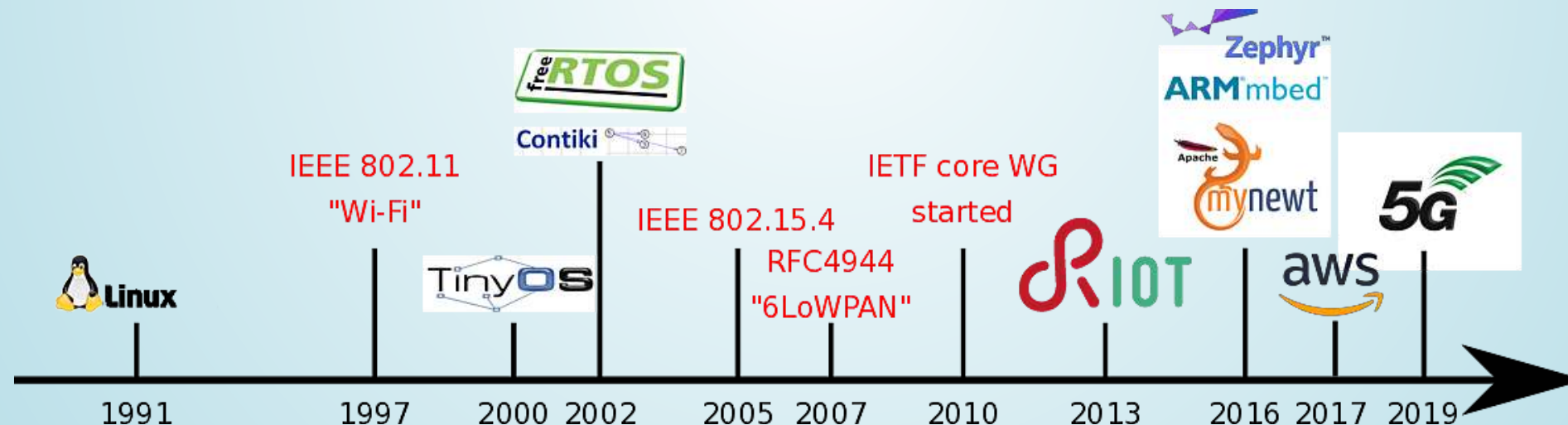
# INTRODUCTION

# THE INTERNET OF THINGS

*What is the Internet of Things?*

# A BRIEF HISTORY OF THE INTERNET OF THINGS

- A Coca-Cola vending machine was connected to the Internet at Carnegie Mellon University
- The *Smart Dust* research proposal at Berkeley kick-started research on *Wireless Sensor Networks (WSNs)*
- Kevin Ashton (P&G) coined the term *Internet of Things*
- Cisco identified the *birth* of IoT by the tipping point “when more ‘things or objects’ were connected to the Internet than people”.





# USE CASES

Mobile Health  
Building & Home  
Automation  
Industrial  
Automation  
Micro & Nano  
Satellites



# CHALLENGES

*What are the main challenges and research areas for the Internet of Things?*

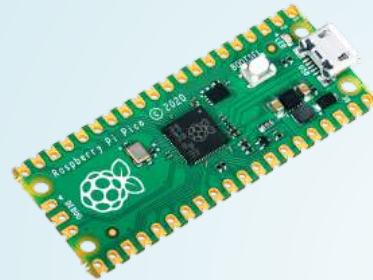
# CONSTRAINTS AND REQUIREMENTS

## Low-end IoT Devices: Limited Resources (RFC7228)

Arduino Due



Raspberry Pi Pico



nRF52840 Dongle



- Memory < 1 Mb
- CPU < 100 MHz
- Energy < 10 Wh

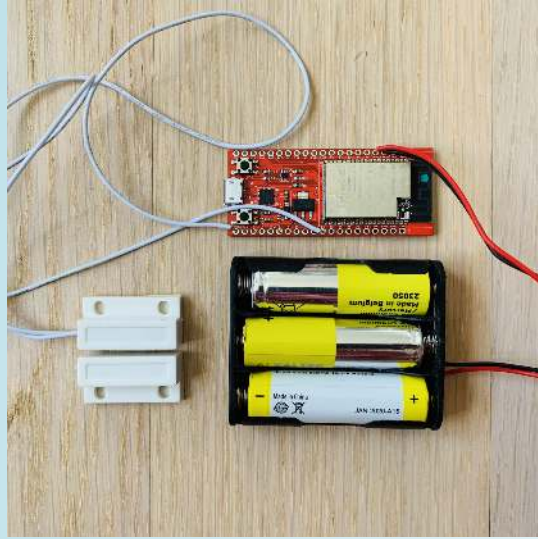
## Application Requirements

- Interoperability
- Energy Efficiency
- Reliability
- Latency
- Low Cost Factor
- Autonomy
- Security
- Scalability
- Sustainability
- Privacy
- Safety

# RESEARCH FIELDS



# EVOLUTION OF LOW-POWER HARDWARE



- Small microcontrollers are getting more and more powerful, energy-efficient, secure, and/or cheaper
- What are the latest developments?
- Which impact does this have on software design?

# PROGRAMMING LOW-END IOT DEVICES

THE  
**C**  
PROGRAMMING  
LANGUAGE



- Requirements and constraints of low-end IoT devices influences the choice of the programming language
  - Available compiler (+ toolchain)
  - Tooling (IDE, debugger etc.)
  - Size of resulting binaries
  - Access to hardware
  - Safety and security concerns
  - Learning curve
  - Feature set

# OPERATING SYSTEMS FOR LOW-END IOT DEVICES

- The particular challenges of IoT applications mandate for new operating systems
- Typical candidates are:
  - RIOT
  - Zephyr
  - mbedOS
  - FreeRTOS
  - mynewt
  - Contiki
  - Linux
- What about standards like POSIX for these OS?



# ENERGY-EFFICIENT WIRELESS PROTOCOLS



- (Wireless) Communication is typically one of the biggest energy consumer for low-end IoT devices
- Hence, efficient technologies are required

- Examples

- IEEE 802.15.4
- BLE
- IEEE 802.11ah

# THE IOT NETWORK STACK

- Integration of constrained-node networks into the Internet
- Adaptation of traditional Internet Protocols
- Standardization and interoperability efforts

## Traditional Internet

HTTP
TCP
OSPF
IPv6
IEEE 802.11, Ethernet

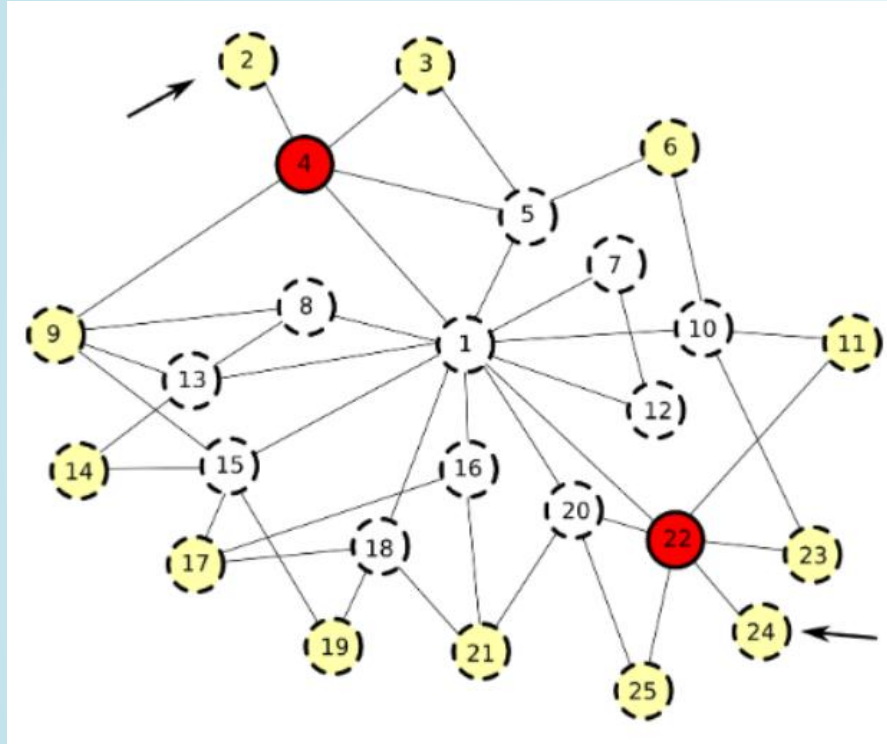
## Layer

Content Aware
Transport
Routing
Network
Medium Access

## IoT

CoAP
UDP
RPL
6LoWPAN
IEEE 802.15.4, BLE

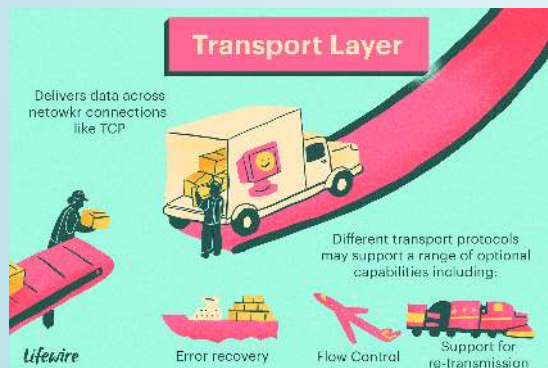
# ROUTING PROTOCOLS FOR CONSTRAINED NETWORKS



- The constraints and requirements of (low-power) IoT networks pose new challenges on the routing protocols to be used inside and between local IoT networks.
- Survey the evolution of WSN routing protocols.
- RPL, its flavors, and what else?
- MANET protocols?

# TRANSPORT LAYER ISSUES FOR CONSTRAINED-NODE NETWORKS

- Many (low-end) IoT solutions are in favor of UDP on the transport layer because of its low complexity and lightweight
- However, many traditional backend solutions (like MQTT or HTTP) are based on TCP
- Most recently a new Internet transport layer has evolved: QUIC
- What is the current state and what are the perspectives?
- What are challenges and what are the opportunities?



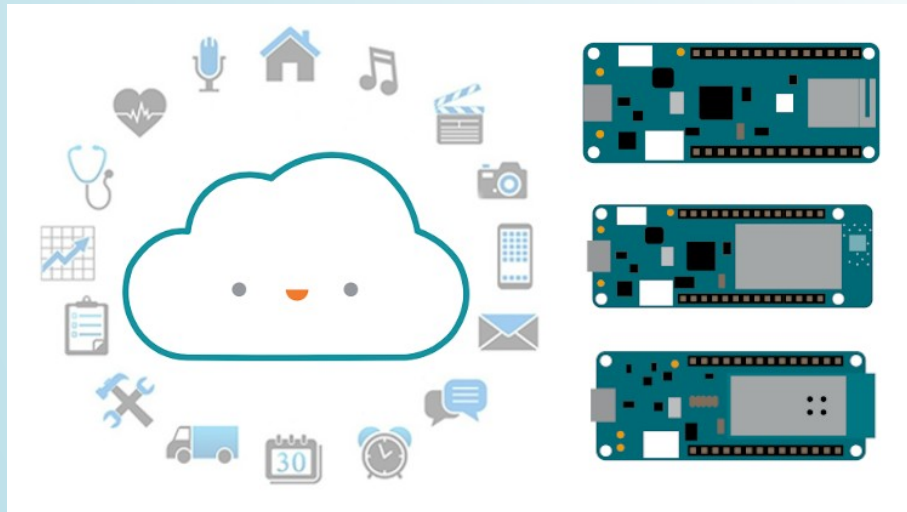


- How to encrypt and sign data in IoT networks?
- Channel security vs. object security
- Cryptography for constrained devices



# CLOUD SOLUTIONS FOR IOT APPLICATIONS

- The backend of an IoT application is typically hosted in the cloud
- IoT cloud providers offer various services like providing endpoints, data processing, device management, or software update services
- Multiple commercial cloud providers exist
  - Azure IoT Hub
  - Google Cloud
  - AWS IoT



# SOFTWARE UPDATES FOR IOT SYSTEMS



- Software updates for IoT systems is a crucial cornerstone of security.
- SUIT and what else?
- Problems, challenges, approaches

# SURVEY ON IOT APPLICATIONS

- Is IoT still missing a killer app?
- Many application scenarios: Home automation, building automation, industry automation, mobile health, connected cars
- What are the (economical, ecological ...) benefits from connected devices?





*Any Questions?*