

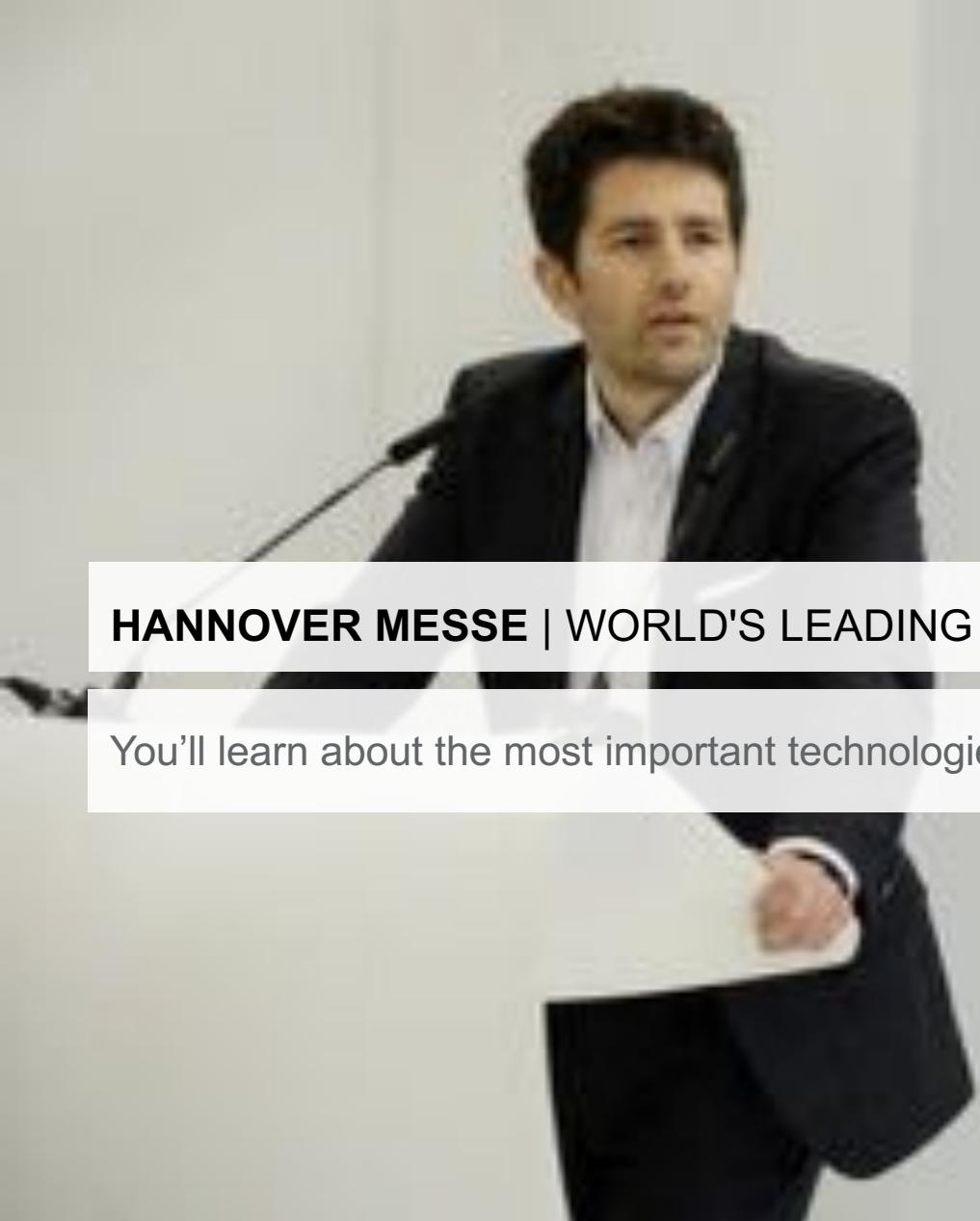
# INDUSTRIAL INTERNET OF THINGS (IIOT)

## PART 1: INTRODUCTION



AV Lecture in Summer Term 2018

Dr.-Ing. Alexander **Willner**

A medium shot of a man with dark hair, wearing a dark suit jacket over a white shirt, speaking into a black microphone. He is positioned on the left side of the frame, with a plain white wall behind him.

CONNECT  
Hannover

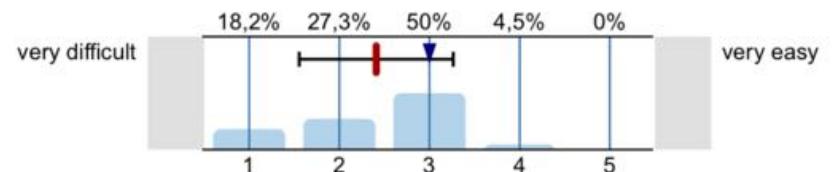
## HANNOVER MESSE | WORLD'S LEADING TRADE FAIR FOR INDUSTRY 4.0

You'll learn about the most important technologies and paradigms currently available.

## **WARNING | DON'T EXPECT THIS LECTURE TO BE EASY**

- “Too many slides [...] who can ever understand every one of them in detail?”
- “It is very theoretical and taking notes is really hard.”

How difficult is the lecture compared to your other lectures?



## **SOME ORIENTATION**

5 minutes

# ABOUT ME



Dr.-Ing. Alexander **Willner**

**Fraunhofer FOKUS**

Software-based Networks (NGNI) Business Unit  
**Head of the Industrial Internet of Things (IIoT) Center**  
alexander.willner@fokus.fraunhofer.de



**Technische Universität Berlin**

Next Generation Networks (AV) Chair  
**Head of the IIoT Research Group & Lecturer**  
alexander.willner@tu-berlin.de



[linkedin.com/in/willner](https://www.linkedin.com/in/willner)



@AlexWillner



[xing.to/willner](http://xing.to/willner)



www <http://iiot-center.org>

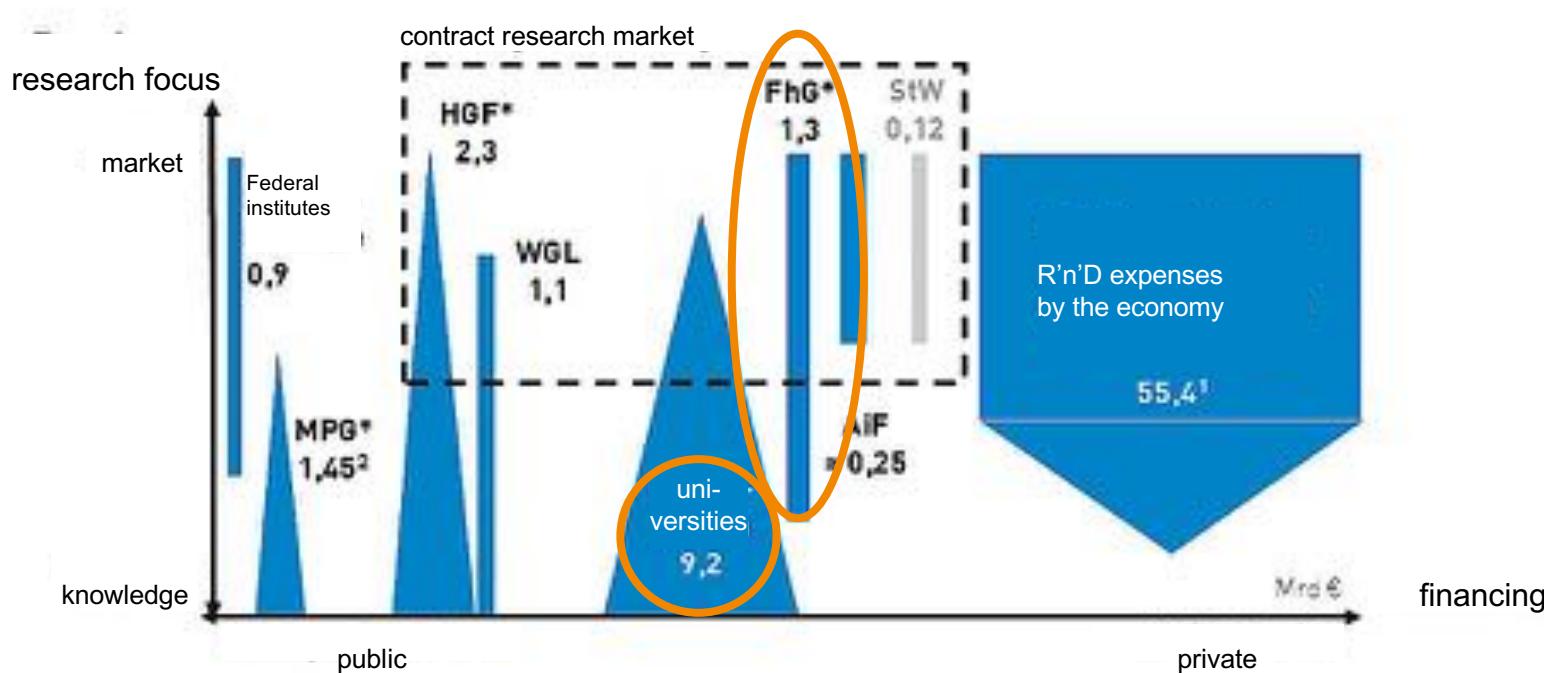
www <http://openiotfog.org>

FRAUNHOFER SOCIETY FOR THE ADVANCEMENT OF APPLIED RESEARCH



Fraunhofer

# COMPARISON WITH OTHER RESEARCH ORGANIZATIONS



HGF Hermann von Helmholtz-Gemeinschaft

WGL Wissenschaftsgemeinschaft Gottfried Wilhelm Leibniz

AIF Arbeitsgemeinschaft industrieller Forschungsvereinigungen

MPG

FhG

StW

Max-Planck-Gesellschaft

Fraunhofer Gesellschaft

Steinbeis-Stiftung

\* Schätzung Wissenschaftsstatistik für 2006, Stifterverband

: 2006

\* Gesamtneuauslast

# THE FRAUNHOFER SOCIETY WORLDWIDE



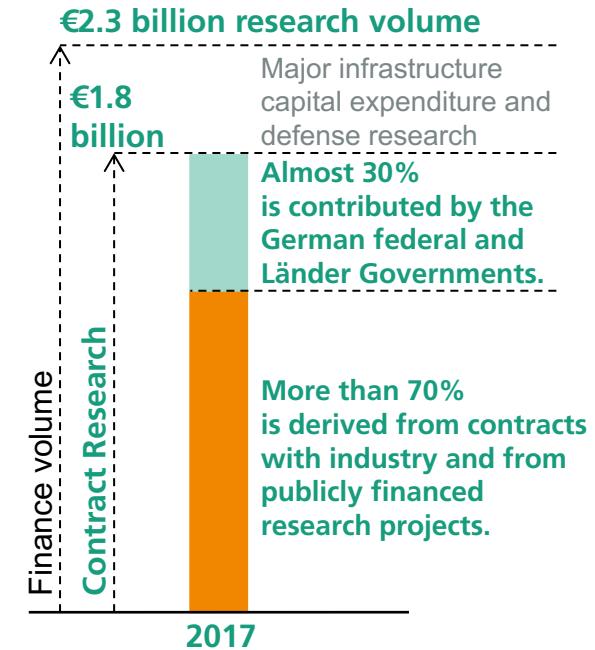
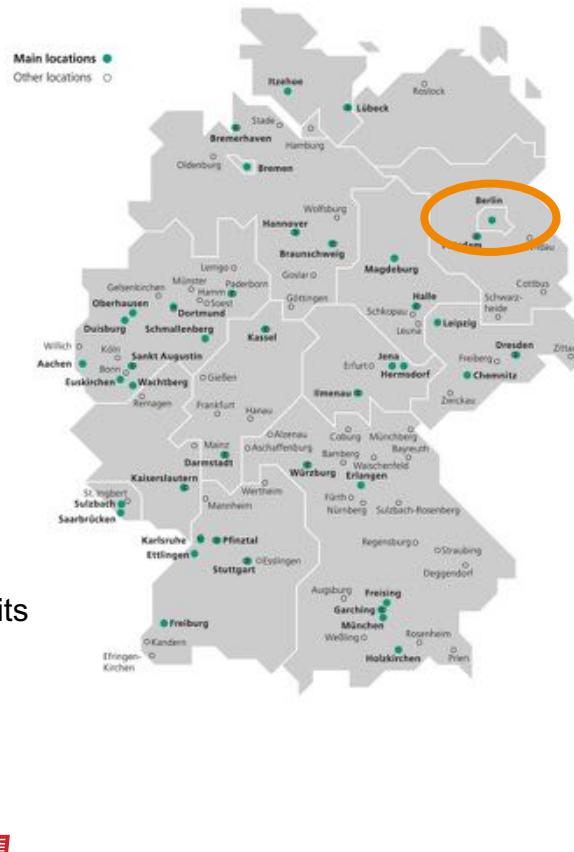
# EUROPE'S LARGEST APPLICATION-ORIENTED NON-PROFIT RESEARCH ORGANIZATION



> 25,000 staff



81 institutes and research units



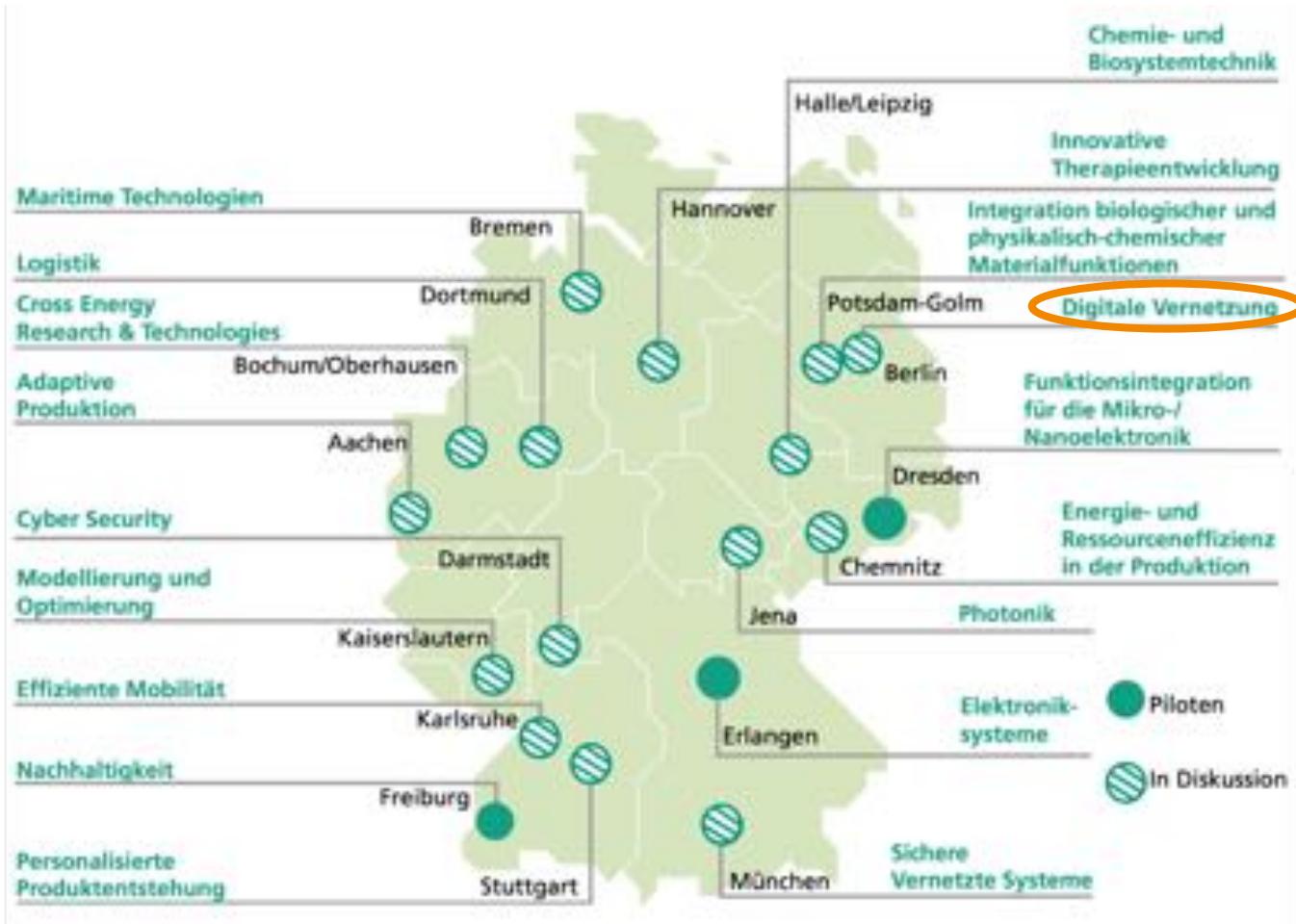
# 7 FRAUNHOFER GROUPS



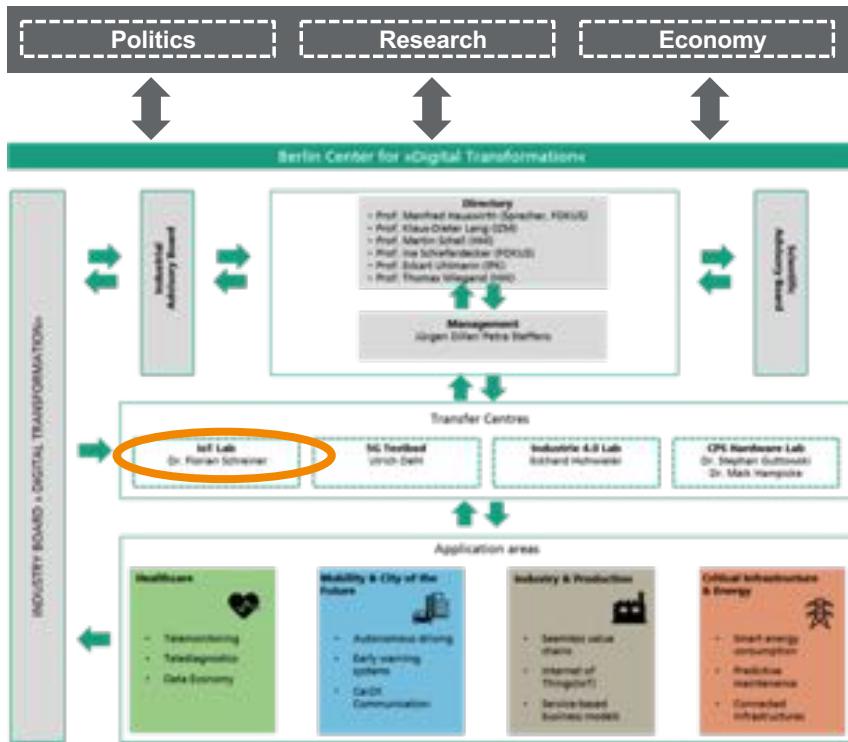
- ICT
- Life Sciences
- Light & Surfaces
- Microelectronics

- Production
- Materials and Components
- Defense and Security

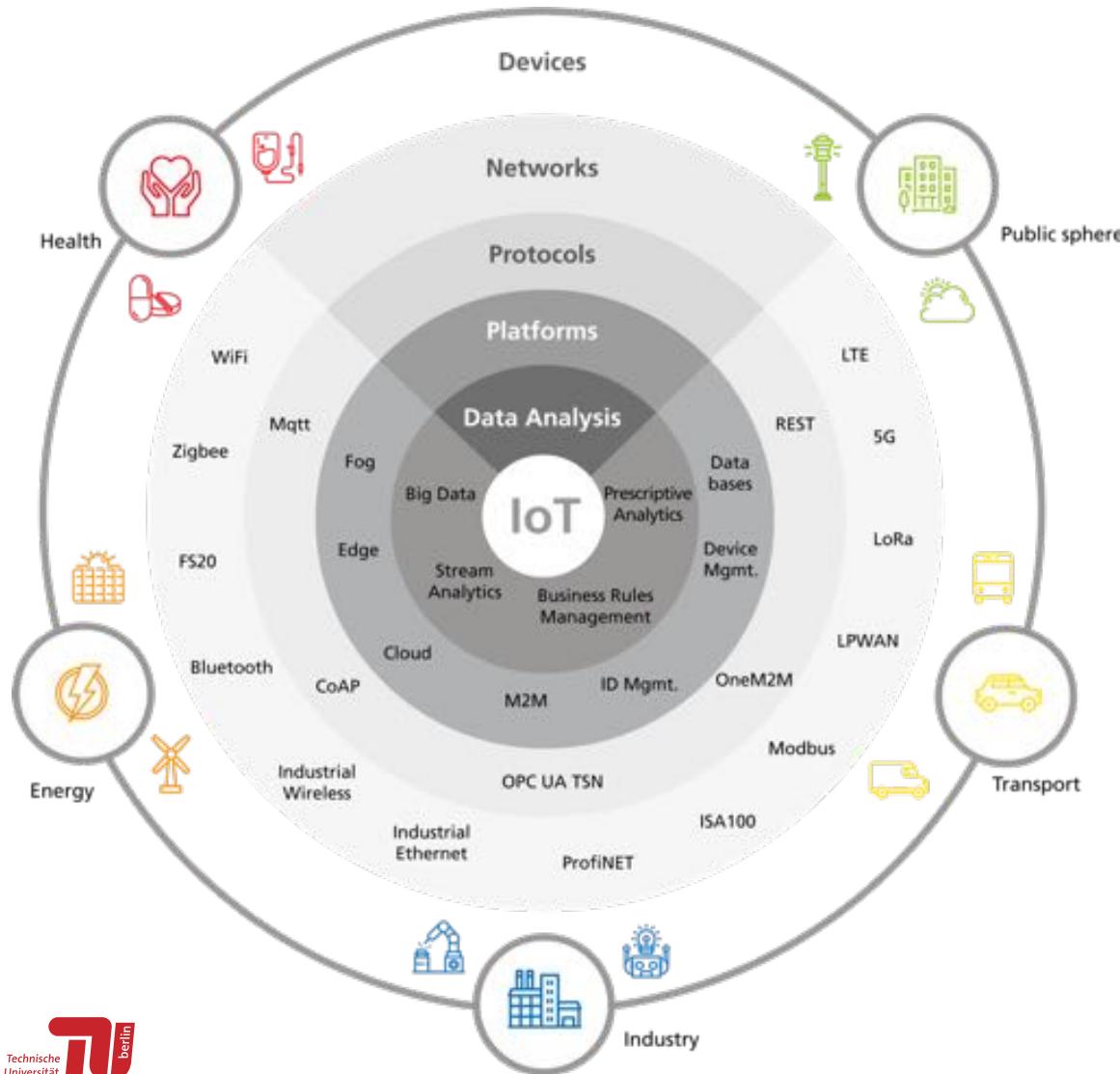
# 18 CENTERS



# BERLIN CENTER FOR DIGITAL TRANSFORMATION



# IOT LAB – DOMAINS AND TECHNOLOGIES



THE FRAUNHOFER INSTITUTE FOR OPEN COMMUNICATION SYSTEMS



# Fraunhofer FOKUS



# THE FRAUNHOFER INSTITUTE FOR OPEN COMMUNICATION SYSTEMS

BMI	BMVi
BSI	BMWi
BMBF	BMG
Senate of Berlin	

**Physical world**

Things      Processes      People

FU Berlin	HU Berlin
Univ. Potsdam	TU Berlin
UdK Berlin	



**"DIGITAL**

**NETWORKING"**

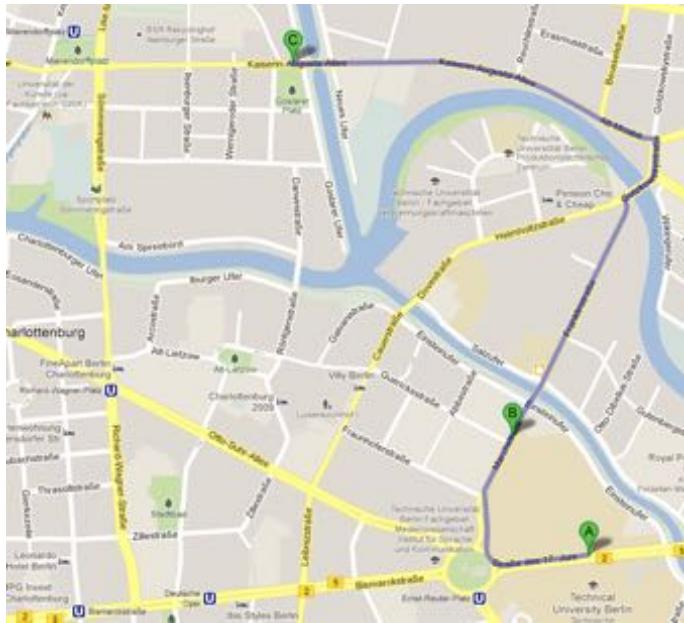
Data and information      Communication networks      Service platforms      Business processes      Applications and services      Identities      Analyses

**Digital world**

# FRAUNHOFER FOKUS @ TUB



# FRAUNHOFER FOKUS @ TUB



# FRAUNHOFER FOKUS @ TUB



- Education of young talents
- Applied Research: 5G and IIoT
- Prototyping
- Key target:  
excellent and sustainable research



- Industry driven future communication technologies research & development.



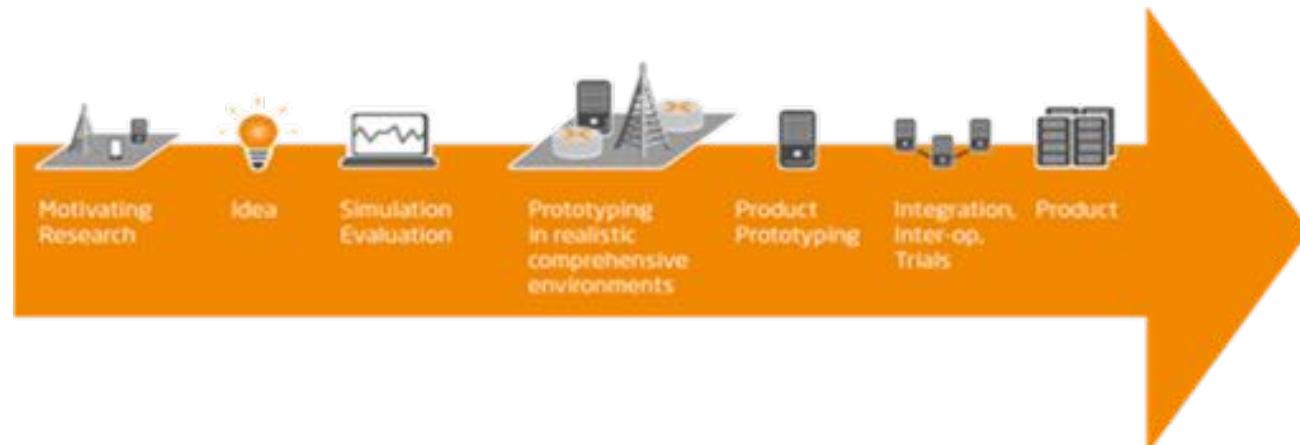
# EVOLUTION TOWARDS CONVERGED NETWORKS

- 
- converge
- Telecommunications
  - Internet
  - Entertainment
  - IT
  - OT
- 5G: IP-based Next Generation (Mobile) Networks forming the technical foundation.
  - IIoT: IP-based Next Generation (Industrial) Networks forming the technical foundation.
- Service Delivery Platforms
  - **Software defined infrastructures & communication**
  - Underlying networks and devices

# FRAUNHOFER FOKUS RESEARCH

## Research activities:

- Initial presentations of opportunities of new technologies
- Innovation and IPR protection
- Design and specification, practical prototyping within a comprehensive testbed
- Qualitative and quantitative evaluations and intuitive demonstrations
- Algorithms and optimizations
- Integration and interoperability



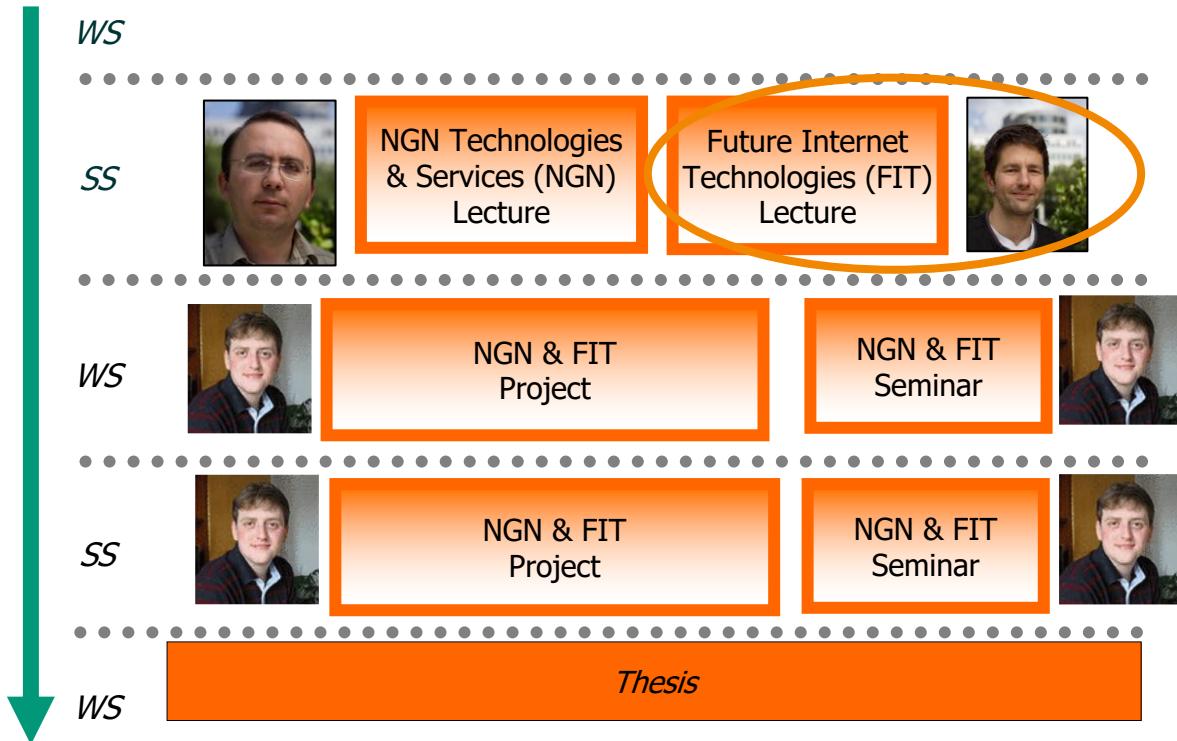
## SOME ORIENTATION

End

## **THE CURRICULUM**

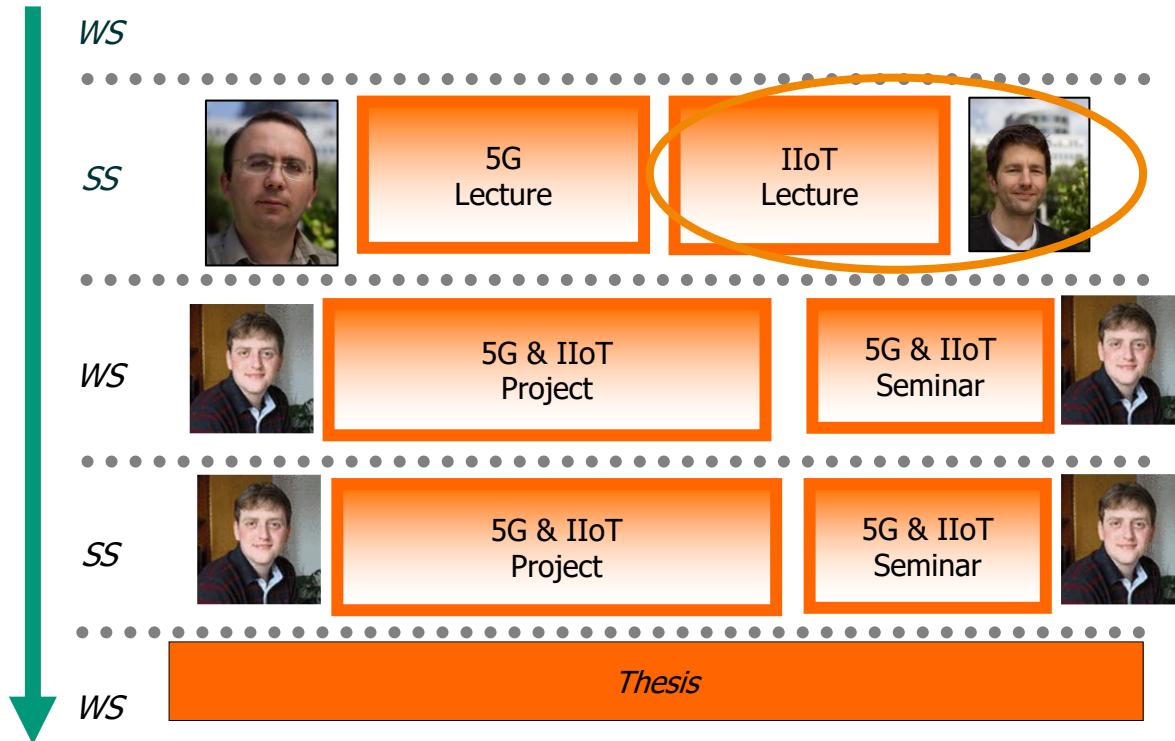
40 minutes (incl. questions)

# AV CURRICULUM (-2017)



[av.tu-berlin.de/teaching](http://av.tu-berlin.de/teaching)

# AV CURRICULUM (2017++)

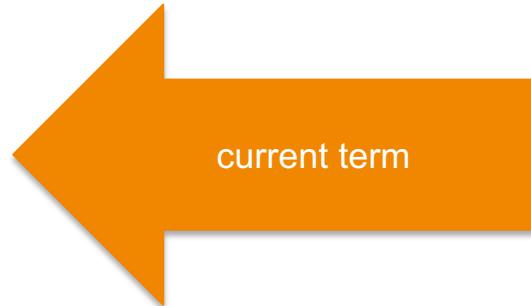


[av.tu-berlin.de/teaching](http://av.tu-berlin.de/teaching)

# AV CURRICULUM

## Summer Term

- 5G Lecture
- IIoT Lecture
- 5G & IIoT Project
- 5G & IIoT Seminar



## Winter Term

- 5G & IIoT Project
- 5G & IIoT Seminar

[av.tu-berlin.de/teaching](http://av.tu-berlin.de/teaching)

## Enrolment Process

- **ALL students:** Join the ISIS course
- **ERASMUS students:** Let us know via e-mail that you want to write the exam till (incl. your registration number and your program of study). It might be required that we sign a paper for you every time you attend the lecture. After taking the exam on July 06th you will receive a certificate that you have to pick it up from our office.
- **OTHER students (the majority):** Register via QISPOS to the module. Registration time: 20.04.2018 - 29.06.2018. In case you register on paper at Prüfungsamt, please bring the copy of your registration (yellow sheet) to our office.

## Modules vs. Courses

- All students are welcome to take the IIoT lecture (only), however, depending on what you study there might be limitations
- Since 2018 the IIoT module (6 ECTS) contains only the IIoT lecture (6 ECTS, due to extended content) and the IIoT seminar (3 ECTS) is in its own module
- Till 2017 the IIoT module (6 ECTS) contained the IIoT lecture (3 ECTS) and the IIoT seminar (3 ECTS)

[av.tu-berlin.de/teaching](http://av.tu-berlin.de/teaching)

# COURSES OF STUDY

- ICT Innovation MSc (PO 2012)
- Informatik BSc / MSc / D
- Elektrotechnik BSc / MSc / D
- Technische Informatik BSc / MSc / D
- Technomathematik BSc / MSc
- Wirtschaftsingenieurw. MSc/Inf.- u.Komm.systeme
- Wirtschaftsinformatik BSc / Msc (PO 2013)
- Wirtschaftsingenieurwesen BSc / MSc / D
- Wirtschaftsingenieurwesen-Inform.-u.Komm.systeme
- Wirtschaftsingenieurwesen MSc/Elekrotechnik

[av.tu-berlin.de/teaching](http://av.tu-berlin.de/teaching)

# AV MODULE OVERVIEW (-2017)

Next Generation Network – Basis 1					
LP (ECTS): 9 / Code: MINF-KS-AV/VL1					
Title	Type	SWS	ECTS	Compulsory	Term
Next Generation Network Technologies & Services (NGN)	VL	4	6	Y	summer
Future Internet Technologies (FIT)	VL	2	3	Y/N	summer
Hot Topics in NGN & FIT	SE	2	3	Y/N	summer / winter

Next Generation Network – Basis 2					
LP (ECTS): 12 / Code: MINF-KS-AV/VL2					
Title	Type	SWS	ECTS	Compulsory	Term
Next Generation Network Technologies & Services (NGN)	VL	4	6	Y	summer
Future Internet Technologies (FIT)	VL	2	3	Y	summer
Hot Topics in NGN & FIT	SE	2	3	Y	summer / winter

[av.tu-berlin.de/teaching](http://av.tu-berlin.de/teaching)

# AV MODULE OVERVIEW (-2017)

## Next Generation Networks & Future Internet Technologies – Project 1

LP (ECTS): 9 / Code: MINF-KS-AV/PJ1

Title	Type	SWS	ECTS	Compulsory	Term
NGN & FIT Project 1	PJ	6	9	Y	summer / winter

## Next Generation Networks & Future Internet Technologies – Project 2

LP (ECTS): 9 / Code: MINF-KS-AV/PJ2

Title	Type	SWS	ECTS	Compulsory	Term
NGN & FIT Project 2	PJ	6	9	Y	summer / winter

## Hot Topics in Next Generation Networks & Future Internet Technologies

LP (ECTS): 3 / Code: MINF-KS-AV/SE

Title	Type	SWS	ECTS	Compulsory	Term
Hot Topics in NGN & FIT	SE	2	3	Y	summer / winter

[av.tu-berlin.de/teaching](http://av.tu-berlin.de/teaching)

# AV MODULE OVERVIEW (2017)

## 5<sup>th</sup> Generation Mobile Networks Lecture

LP (ECTS): 6 / Code: MINF-KS-AV/VL1

Title	Type	SWS	ECTS	Compulsory	Term
5 <sup>th</sup> Generation Mobile Netw. (5G)	VL	4	6	Y	summer

## Industrial Internet of Things Lecture

LP (ECTS): 6 / Code: MINF-KS-AV/VL1

Title	Type	SWS	ECTS	Compulsory	Term
Industrial Internet of Things (IIoT)	VL	2	3	Y	summer
5G & IIoT Seminar	SE	2	3	Y	summer / winter

## 5<sup>th</sup> Generation Mobile Networks & Industrial Internet of Things Project

LP (ECTS): 9 / Code: MINF-KS-AV/PJ1

Title	Type	SWS	ECTS	Compulsory	Term
5G & IIoT Project	PJ	6	9	Y	summer / winter

## 5<sup>th</sup> Generation Mobile Networks & Industrial Internet of Things Seminar

LP (ECTS): 3 / Code: MINF-KS-AV/SE

Title	Type	SWS	ECTS	Compulsory	Term
5G & IIoT Seminar	SE	2	3	Y	summer / winter

[av.tu-berlin.de/teaching](http://av.tu-berlin.de/teaching)

# AV MODULE OVERVIEW (2018++)

## 5<sup>th</sup> Generation Mobile Networks Lecture

Title	Type	SWS	ECTS	Compulsory	Term
5 <sup>th</sup> Generation Mobile Networks (5G)	VL	4	6	Y	summer

## Industrial Internet of Things Lecture

Title	Type	SWS	ECTS	Compulsory	Term
Industrial Internet of Things (IIoT)	VL	4	6	Y	summer

## 5<sup>th</sup> Generation Mobile Networks & Industrial Internet of Things Project

Title	Type	SWS	ECTS	Compulsory	Term
5G & IIoT Project	PJ	6	9	Y	summer / winter

## 5<sup>th</sup> Generation Mobile Networks & Industrial Internet of Things Seminar

Title	Type	SWS	ECTS	Compulsory	Term
5G & IIoT Seminar	SE	2	3	Y	summer / winter

[av.tu-berlin.de/teaching](http://av.tu-berlin.de/teaching)

# 5TH GENERATION MOBILE NETWORKS (5G)

**Lecturer:** Prof. Dr. Thomas Magedanz, Dr.-Ing. Marius Corici

**ECTS:** 6

**Registration:** 20.04.2018 – 06.07.2018 (QISPOS)

**Exam:** 13.07.2018

**Registration:** via ISIS and QISPOS

**Schedule:** Each Friday, 12 - 14 in H2035

- Introduction to 5G and Telecommunication Technologies
- Cloud Technologies & Network Softwarization
- Evolved Packet Core
- Human, Massive IoT and Low Delay ultra reliable communication
- Open Flow, SDN Initiatives, OF in EPC, OpenSDNCore
- 5G Initiatives, Architecture, R&D, Testbeds, Best Practice Examples
- Exercise, Exam, FOKUS Visit + Exam Review

[av.tu-berlin.de/teaching](http://av.tu-berlin.de/teaching)

# INDUSTRIAL INTERNET OF THINGS (IIOT)

**Lecturer:** Dr.-Ing. Alexander Willner

**ECTS:** 6

**Registration:** 20.04.2018 – 29.06.2018 (QISPOS)

**Exam:** 06.07.2018

**Registration:** via ISIS and QISPOS

**Schedule:** Each Friday, 14 - 16 in H2013

- Introduction
- Terminology (CPS, M2M, MTC, Fog, IoT, WoT, GoT, I4.0, ...)
- Connectivity (Wi-Fi, BLE, FS20, LoRa, PROFINET, IEEE TSN, ...)
- Communication (HTTP/MQTT/CoAP/... and ETSI M2M/oneM2M/OPC UA/DDS/...)
- Digital Twin (Semantic Web)
- Programmability (Fog and Edge Computing)
- Exercise, Exam, Review



this lecture

[av.tu-berlin.de/teaching](http://av.tu-berlin.de/teaching)

# 5G & IIOT SEMINAR

**Organisator:** Michael Pauls

**ECTS:** 3

## Schedule

- **23.04.2018:** Kickoff in H2013, 14-16
- **23.04.2018 – 13.07.2018:** Registration via QISPOS and ISIS
- **xx.05.2018:** Topic selection and meeting
- **20.07.2018:** Presentation
- **27.07.2018:** Papers

## Seminar will consist of

- Presentation (50%, 15 min.)
- Written report  
(50%, ~10 pages, IEEE two-columns)

## Basics

- Can be extended to Master/Diploma Thesis
- **No** regular meetings

## Prerequisites

- Conversational English or German
- Previous (at least basic) knowledge of the seminar's topic

# 5G & IIOT PROJECT

**Organisator:** Michael Pauls

**ECTS:** 9

**Schedule:**

- **23.04.2018:** Kickoff in H2013, 14-16
- **23.04.2018 – 20.07.2018:** Registration via QISPOS and ISIS
- **09.05.2018:** Initial concept with a work plan (1<sup>st</sup> presentation)
- **28.06.2018:** Project implementation status report (2<sup>nd</sup> presentation)
- **19.07.2018:** Project outcome with demonstration and conclusions (3<sup>rd</sup> presentation)
- **27.07.2018:** Submission of code and final project report

**Project will consist of**

- 3 presentations (10% each, 15 minutes)
- Implementation (30%)
- Evaluation (20%)
- Documentation (20%, ~15 pages, IEEE two-columns)

**Basics**

- Can be extended to Master/Diploma Thesis
- **No** regular meetings

[av.tu-berlin.de/teaching](http://av.tu-berlin.de/teaching)

# **THE CURRICULUM**

End

## **THE TEAM**

3 minutes

# PROF. DR.-ING. HABIL. THOMAS MAGEDANZ

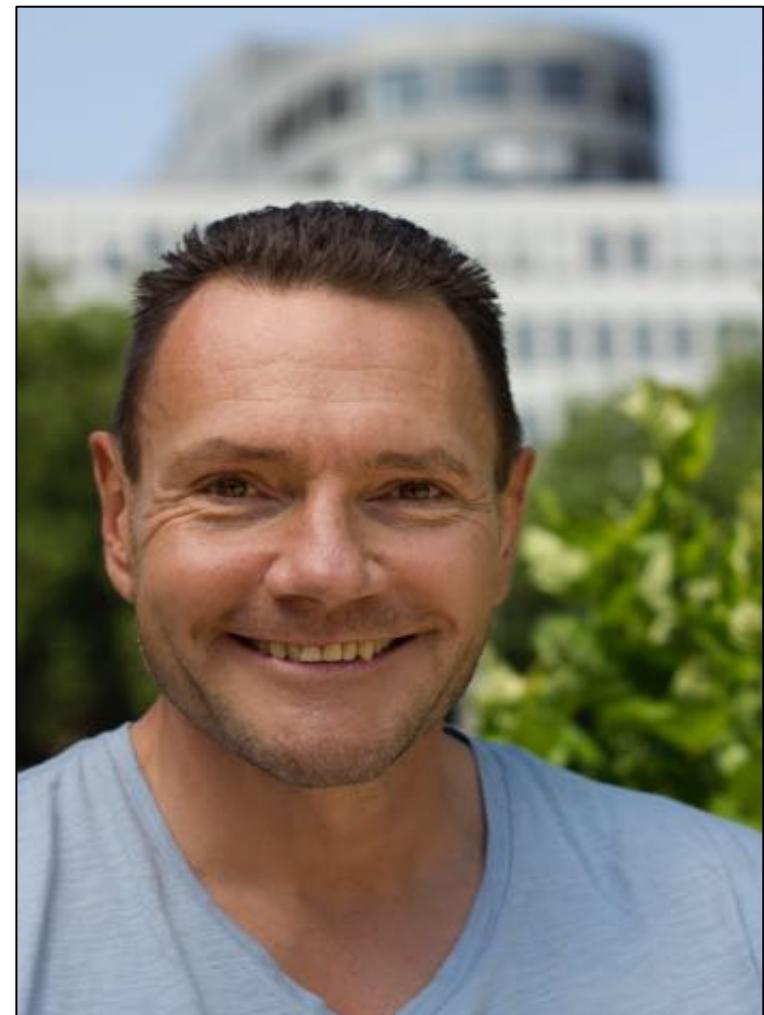
Thomas Magedanz (PhD) is professor in the electrical engineering and computer sciences faculty at the Technical University of Berlin, Germany, leading the chair for next generation networks (Architekturen der Vermittlungsknoten – AV) supervising Master and PhD Students.

In addition, he is director of the “NGNI” division at the Fraunhofer Institute FOKUS, which also provides the national NGN/IMS/EPC/5G test and development centre in Germany. Since 2006 he is also extraordinary professor at the University of Cape Town in South Africa and since 2012 visiting professor at the University of Chile.

Prof. Magedanz is a globally recognised technology expert, based on his 20 years of practical experiences gained by managing various research and development projects in the various fields of today's convergence landscape (namely IT, telecoms, internet and entertainment).

He acts often as invited tutorial speaker at major telecom conferences and workshops around the world.

Prof. Magedanz is senior member of the IEEE, editorial board member of several journals, and the author of more than 200 technical papers/articles. He is the author of two books on IN standards and IN evolution.



## THE AV/NGNI TEAM (EXCERPT)



# FRAUNHOFER FOKUS NGNI ADVISOR TEAM



Dr.-Ing. Marius  
**Corici**



Dr.-Ing. Florian  
**Schreiner**



Ronald  
**Steinke**



Ancuta  
**Corici**

# TEAM OVERVIEW (EXCERPT)

## Core Team



Benjamin  
Reichel



Tran  
Thanh



Lorenzo  
Tomasini



Daniel  
Nehls



Giuseppe  
Carella



Michael  
Pauls



Dr.-Ing.  
Alexander  
Willner



Zahoor  
Ahmed

## Students



Various

## Project Acquisition



Dr. Stefan  
Covaci

## PhD Fellows



Ahmed  
Medhat



Matthias  
de Brito

[av.tu-berlin.de/team](http://av.tu-berlin.de/team)

# TWO PILLARS

## Fifth Generation Mobile Networks (5G)

5G, LTE, SDN, NFV, ...



Michael Pauls  
giuseppe.a.carella@tu-berlin.de



open5Gcore



open5GMTC



## OPEN BATON



[av.tu-berlin.de/research](http://av.tu-berlin.de/research)

## Industrial Internet-of-Things (IIoT)

Connectivity, Communication, Data, Programmability



Dr.-Ing. Alexander Willner  
alexander.willner@tu-berlin.de



## THE IIOT TEAM (EXCERPT, 28 COLLEAGUES IN TOTAL)



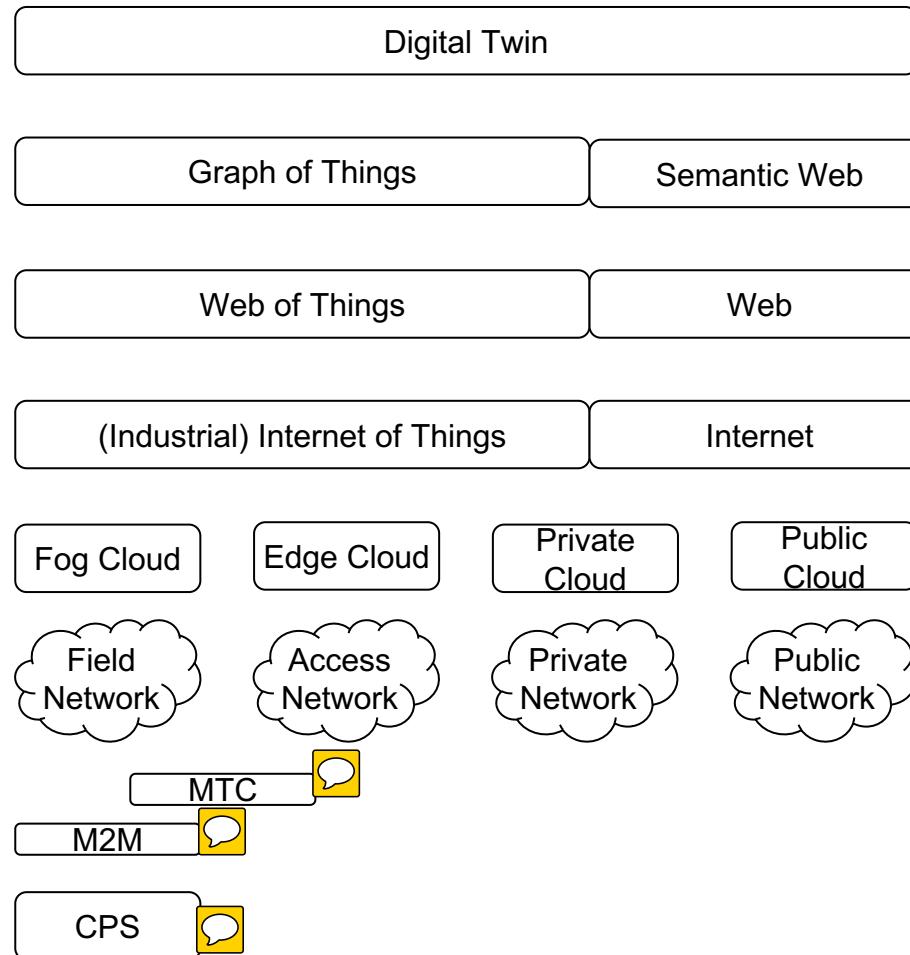
## **THE TEAM**

End

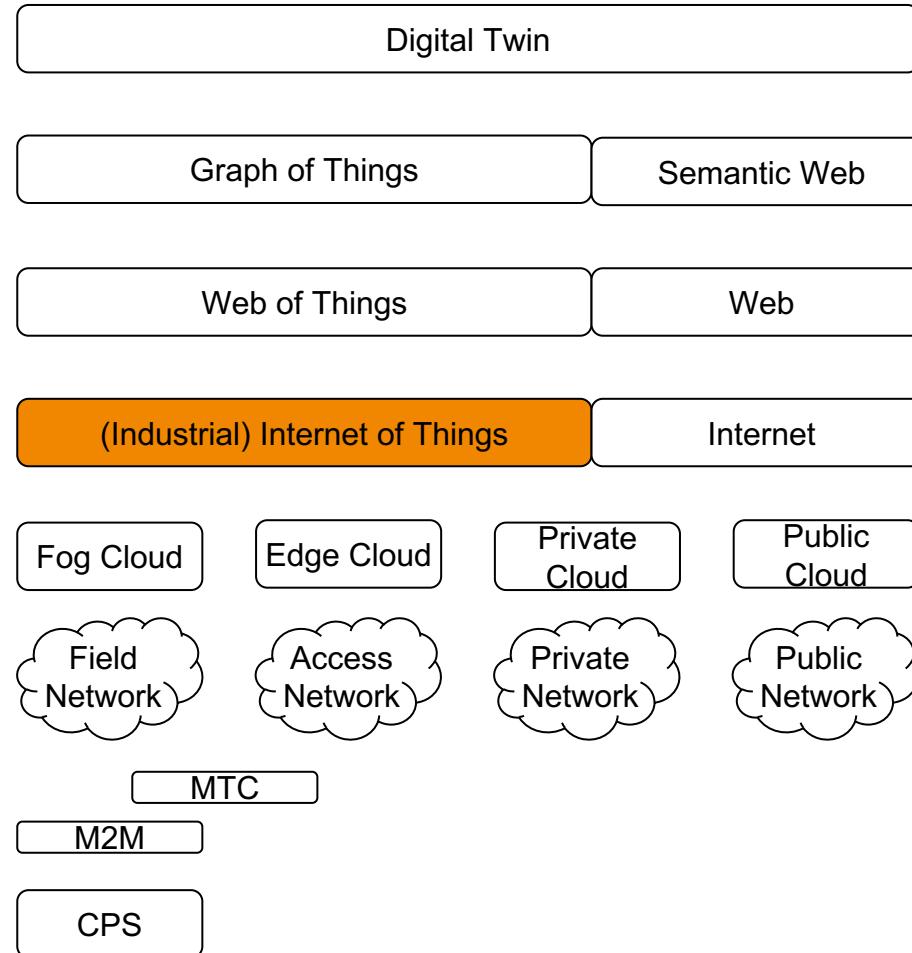
# **THE IIOT LECTURE**

40 minutes

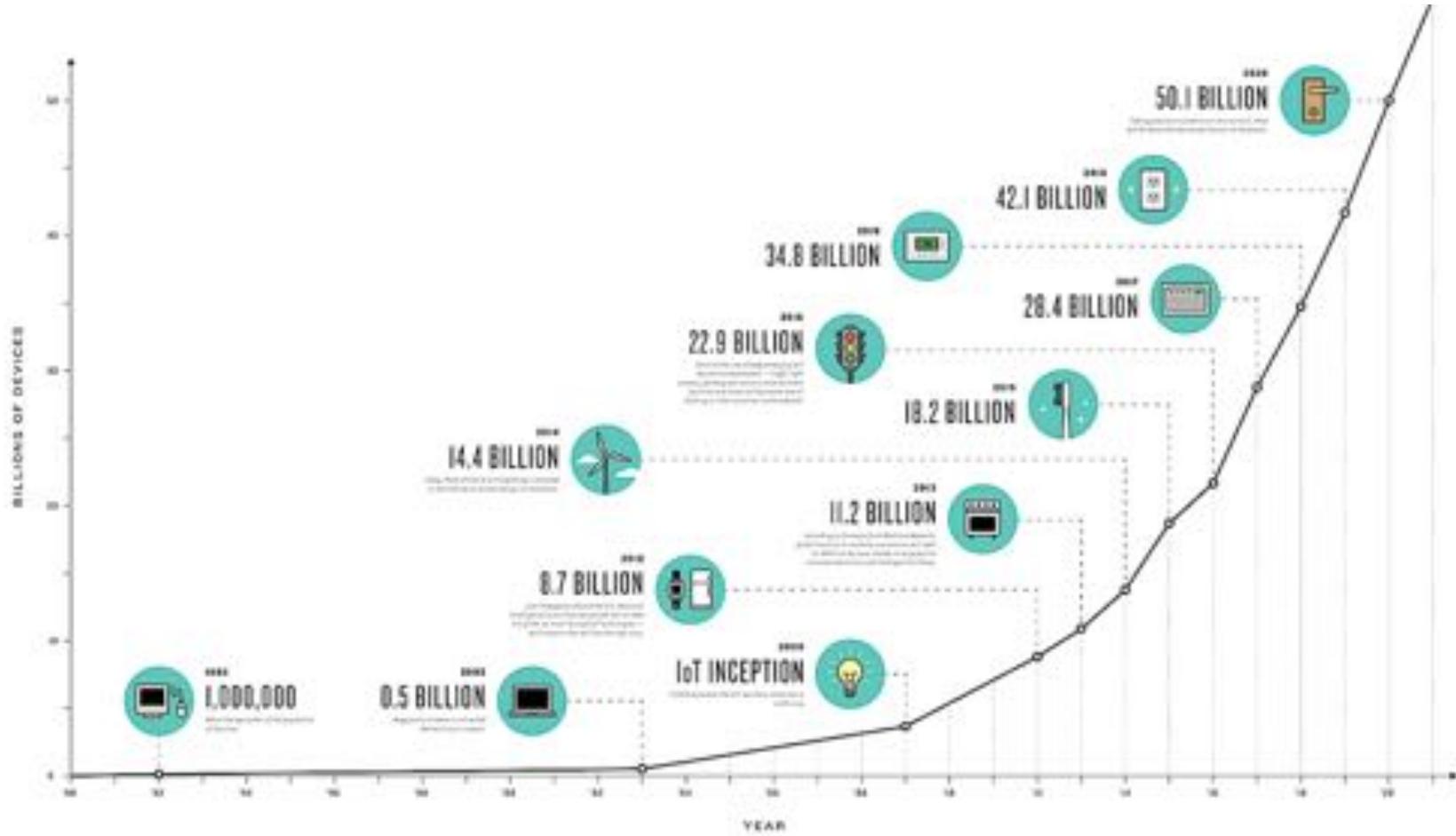
# TERMINOLOGY



# TERMINOLOGY



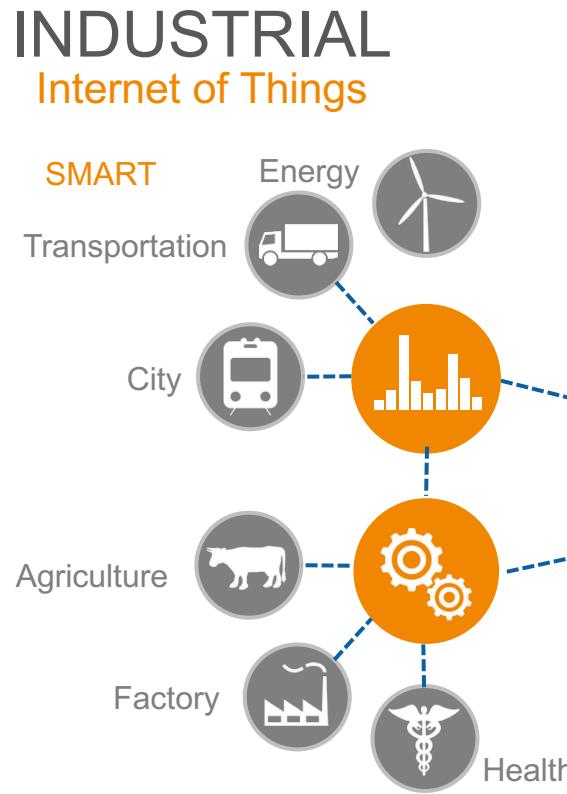
# THE INTERNET OF THINGS



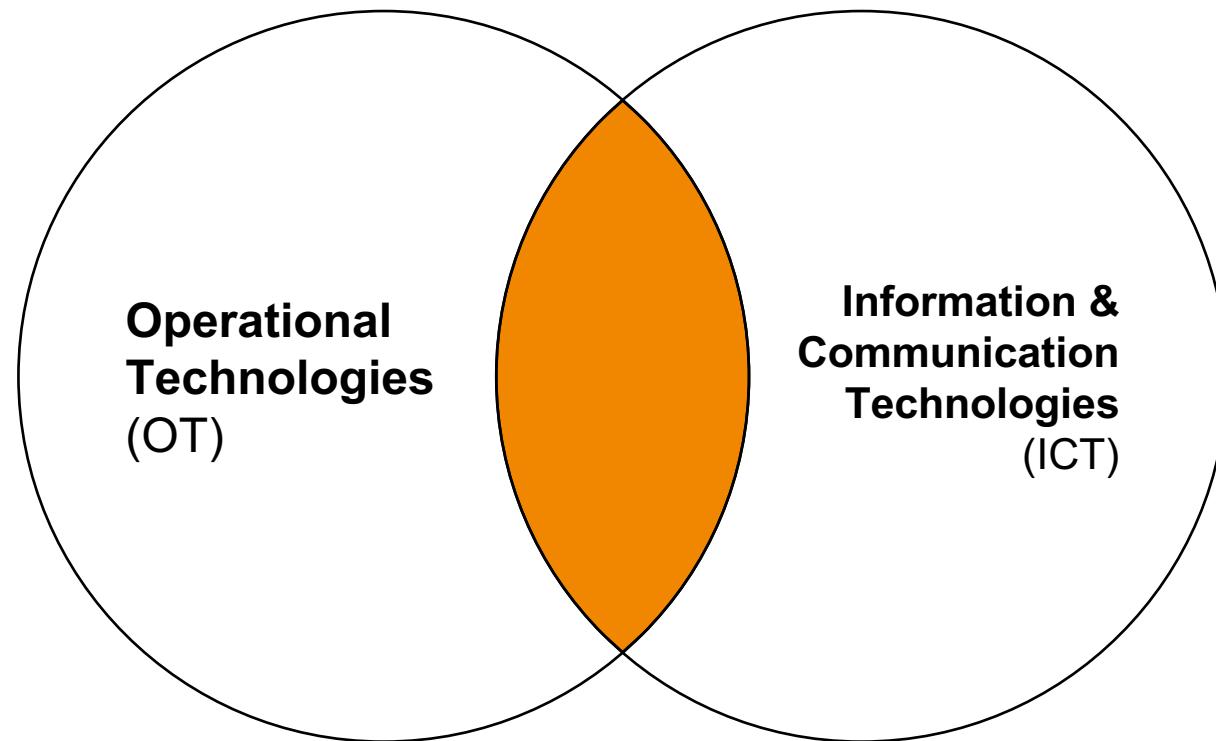
The Connectivist based on Cisco data

# INDUSTRIAL VS. CONSUMER IOT

Based on Texas Instruments and Moor Insights & Strategy's report  
*Segmenting the Internet of Things (IoT)*



# IOT IS THE CONVERGENCE POINT BETWEEN OT & ICT

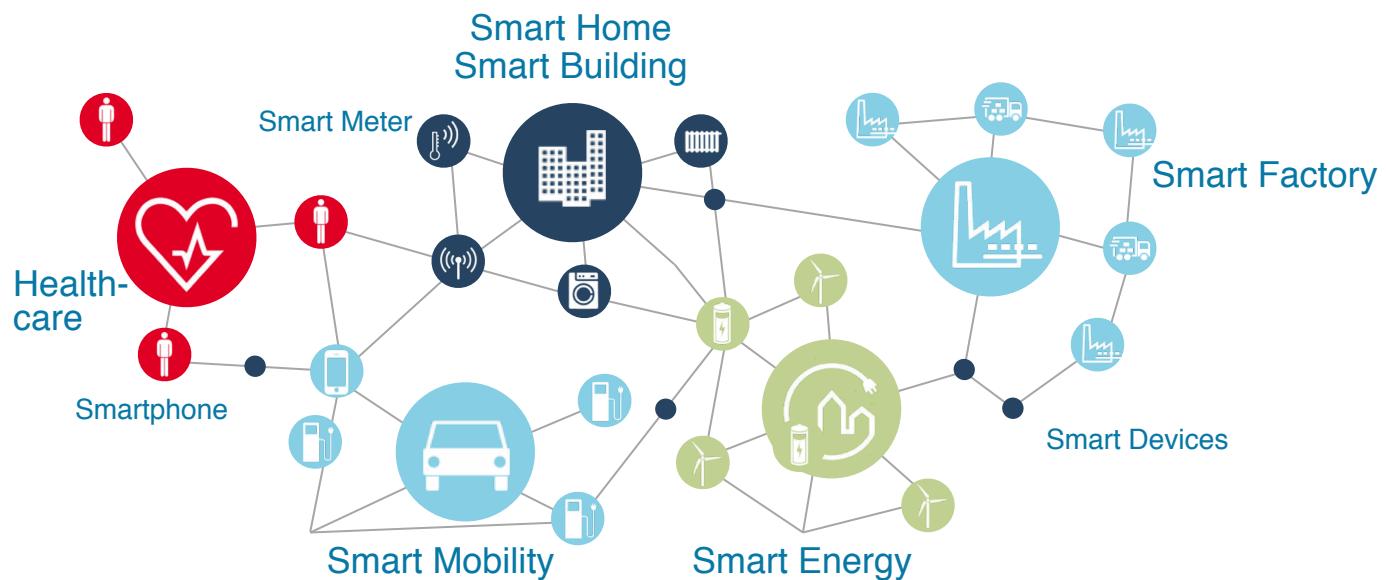


## VIDEO | WHAT'S THE MATTER WITH OWEN?



[https://youtu.be/3xGoBII\\_fdg](https://youtu.be/3xGoBII_fdg)

# VISION: DIGITAL NETWORKING ACROSS THE WHOLE VALUE CHAIN



Based on: Plattform Industrie 4.0 - Graphics © Bosch Rexroth AG

①

the past

②

③

# THE INDUSTRIAL REVOLUTION



## Second Industrial Revolution

**Mass production** based on division of labour and electrical energy

## First Industrial Revolution

**Mechanical production** powered by water and steam

End of 18th century

Start of 20th Century

Start of 70's

The Future

①

②

③

present age

# THE INDUSTRIAL REVOLUTION



**Third Industrial Revolution**  
**Electronics & IT** for further  
automatization of production



## First Industrial Revolution

**Mechanical production** powered by water and steam

End of 18th century

Start of 20th Century

Start of 70's

The Future

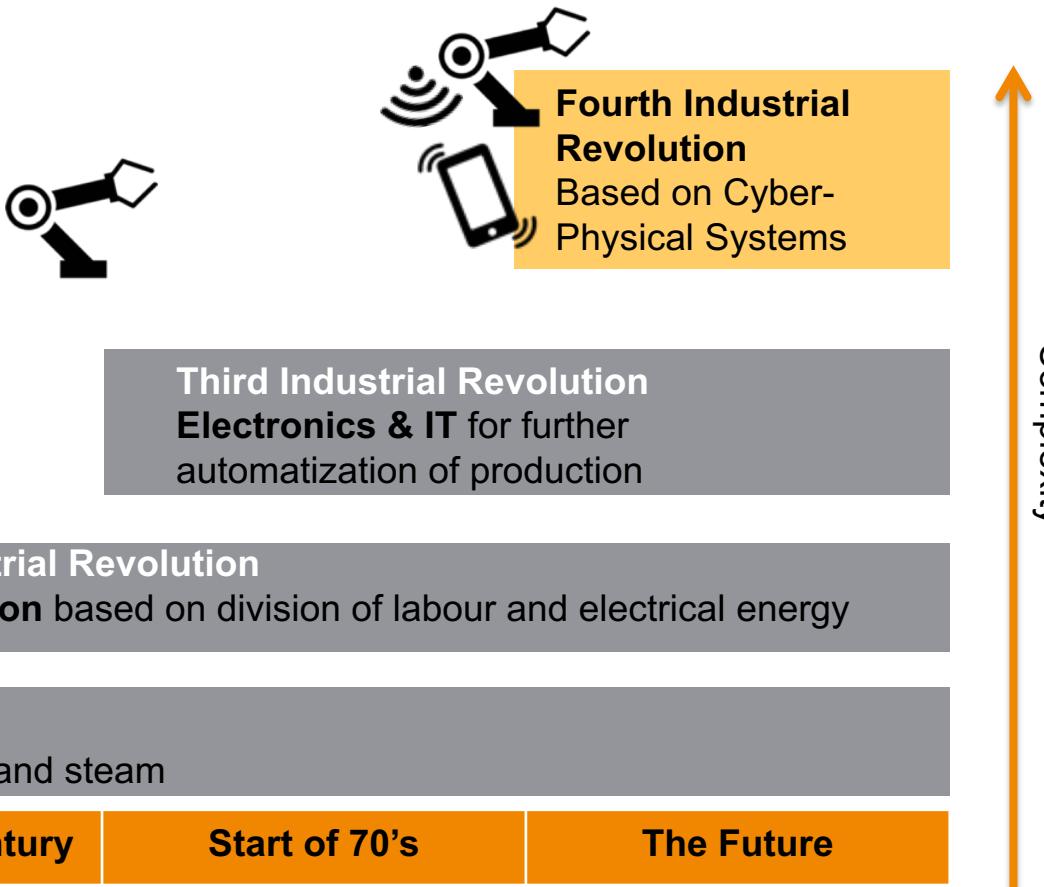
①

②

③

the future

# THE INDUSTRIAL REVOLUTION



## First Industrial Revolution

**Mechanical production** powered by water and steam

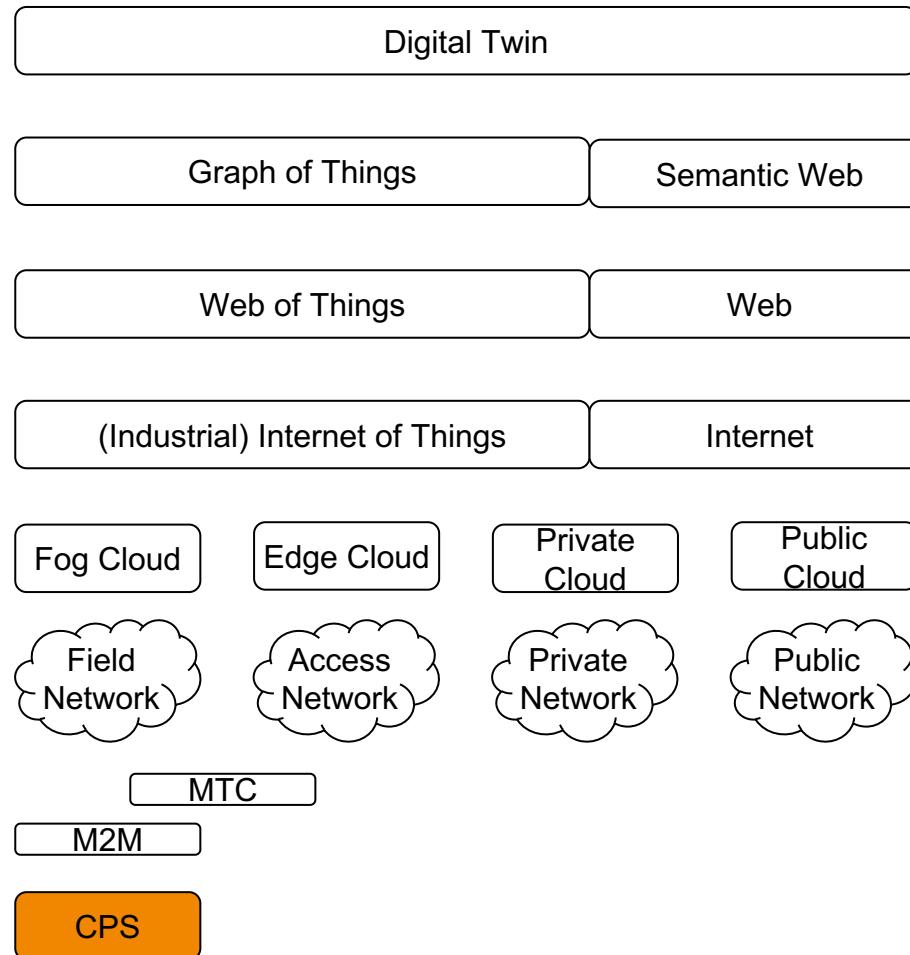
End of 18th century

Start of 20th Century

Start of 70's

The Future

# TERMINOLOGY



# THE IIOT SDOS AND ALLIANCES



# THE INDUSTRIAL INTERNET CONSORTIUM

IIC



An open membership organization bringing together



government,



academia,

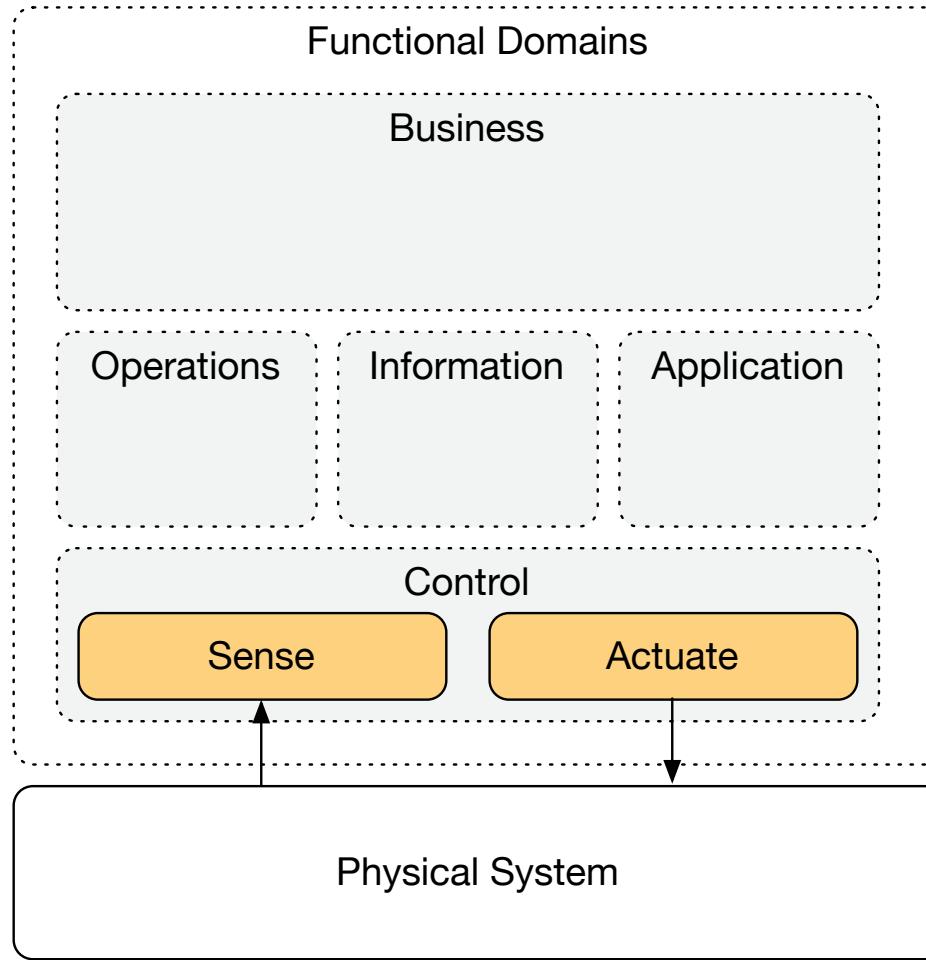


and industry

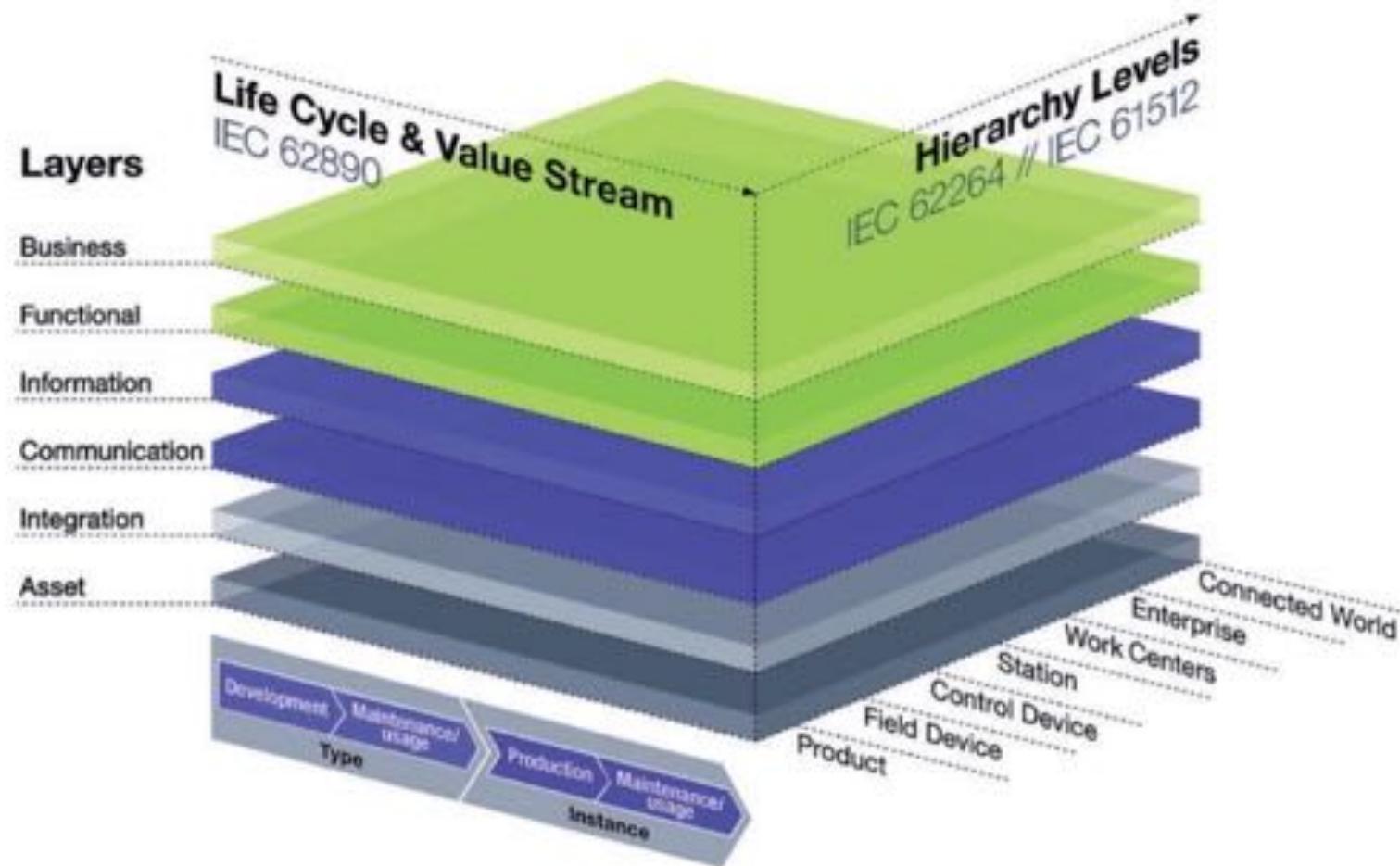
# RELATIONSHIP BETWEEN IIC AND THE PLATTFORM INDUSTRIE 4.0



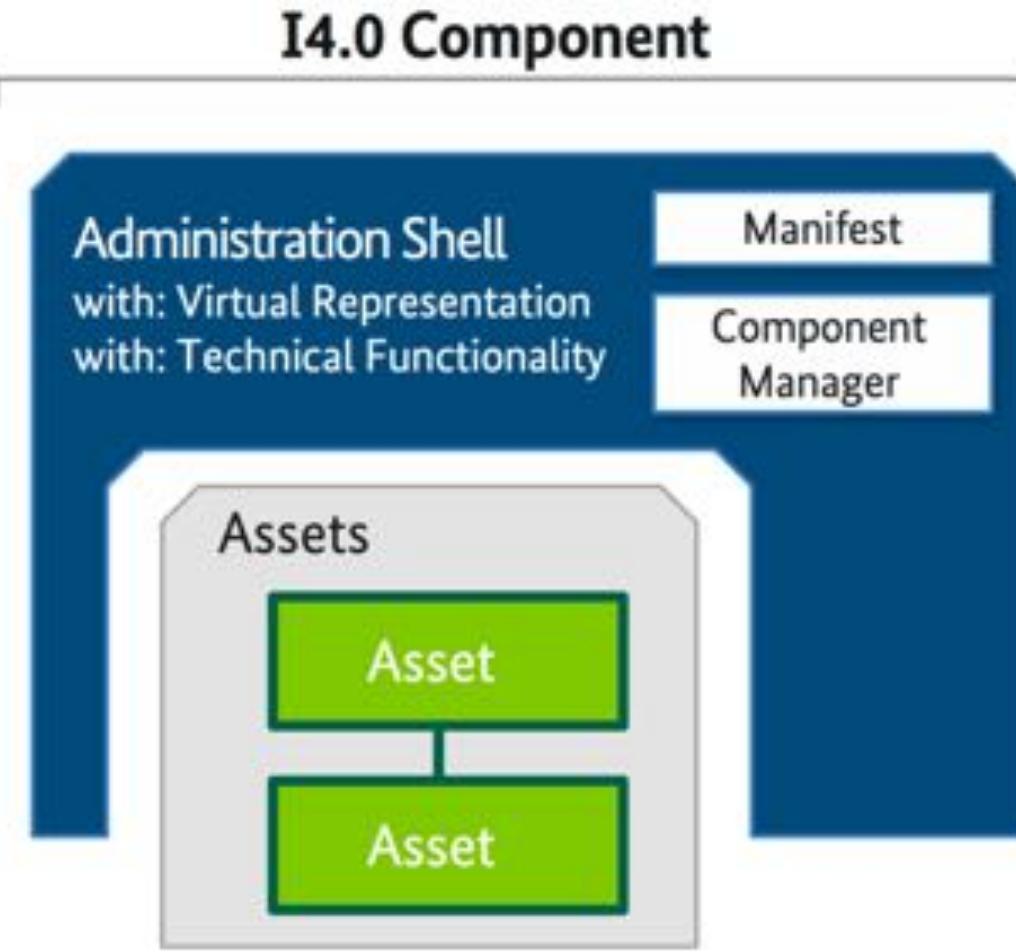
# IIRA – FUNCTIONAL DOMAINS (FOR A CYBER-PHYSICAL SYSTEM)



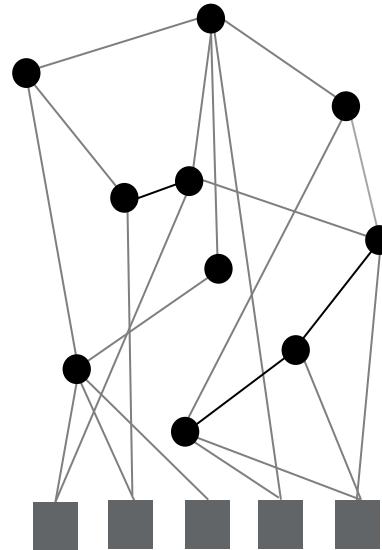
# REFERENCE ARCHITECTURE MODEL INDUSTRY 4.0 (RAMI)



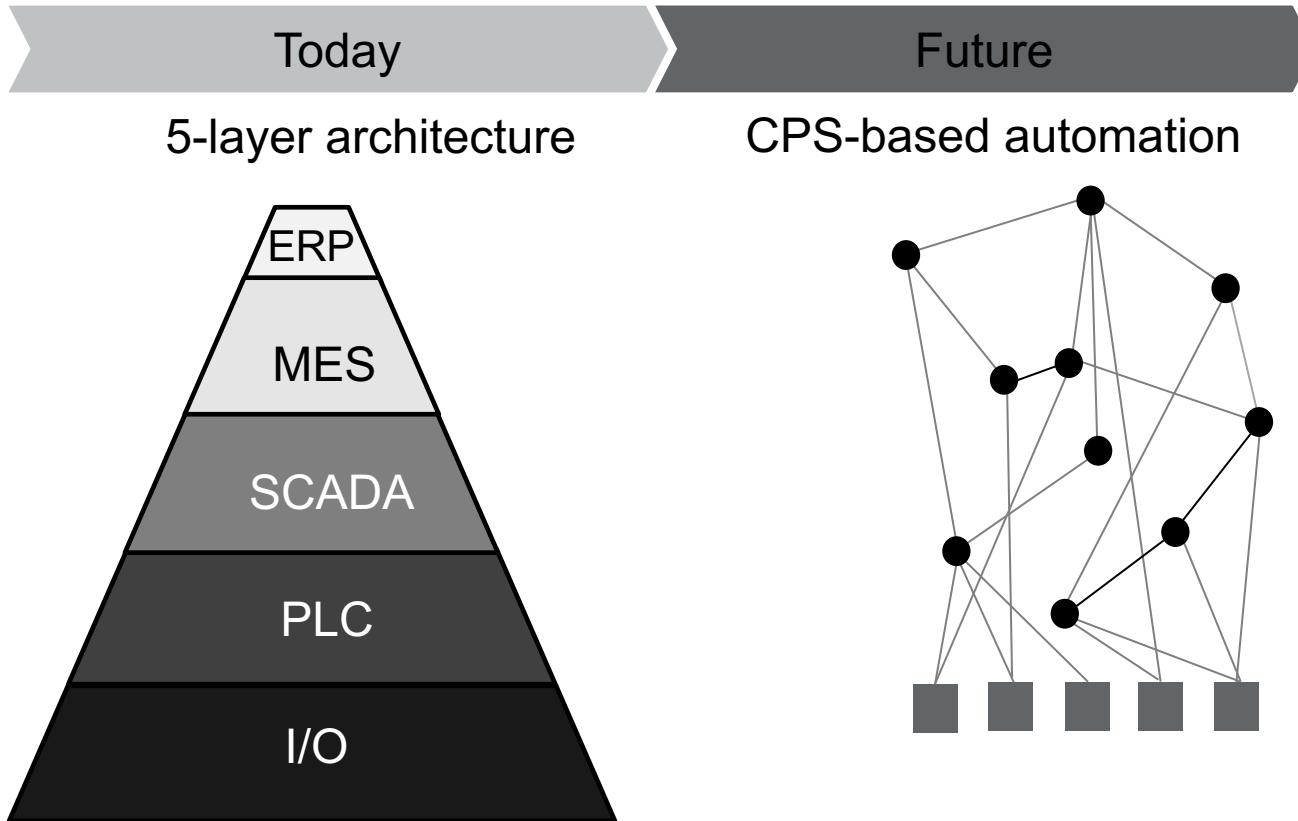
# INDUSTRIE 4.0 COMPONENT (CPS) – ASSET ADMINISTRATION SHELL (AAS)



# CYBER-PHYSICAL SYSTEM (CPS) BASED AUTOMATION



# FROM THE 5-LAYER ARCHITECTURE TO AUTONOMOUS CPS'



## **KEY CHALLENGES & TECHNOLOGIES**

①

Connectivity

②

Communication

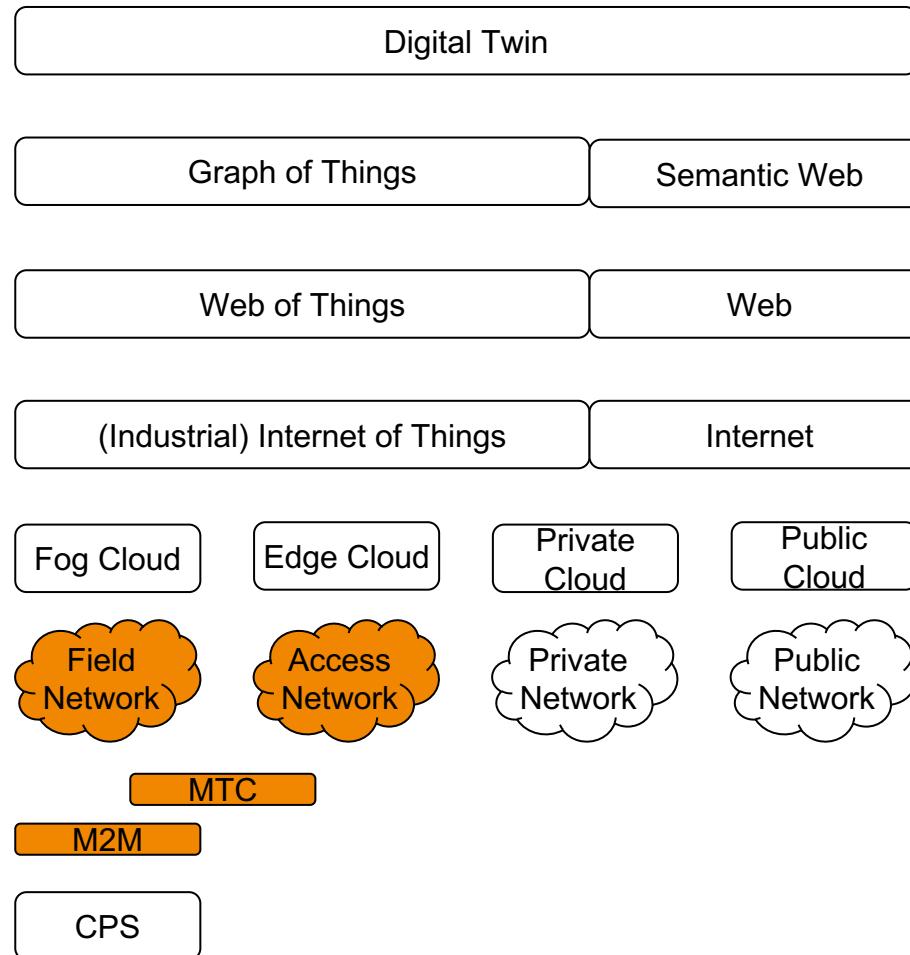
③

Data

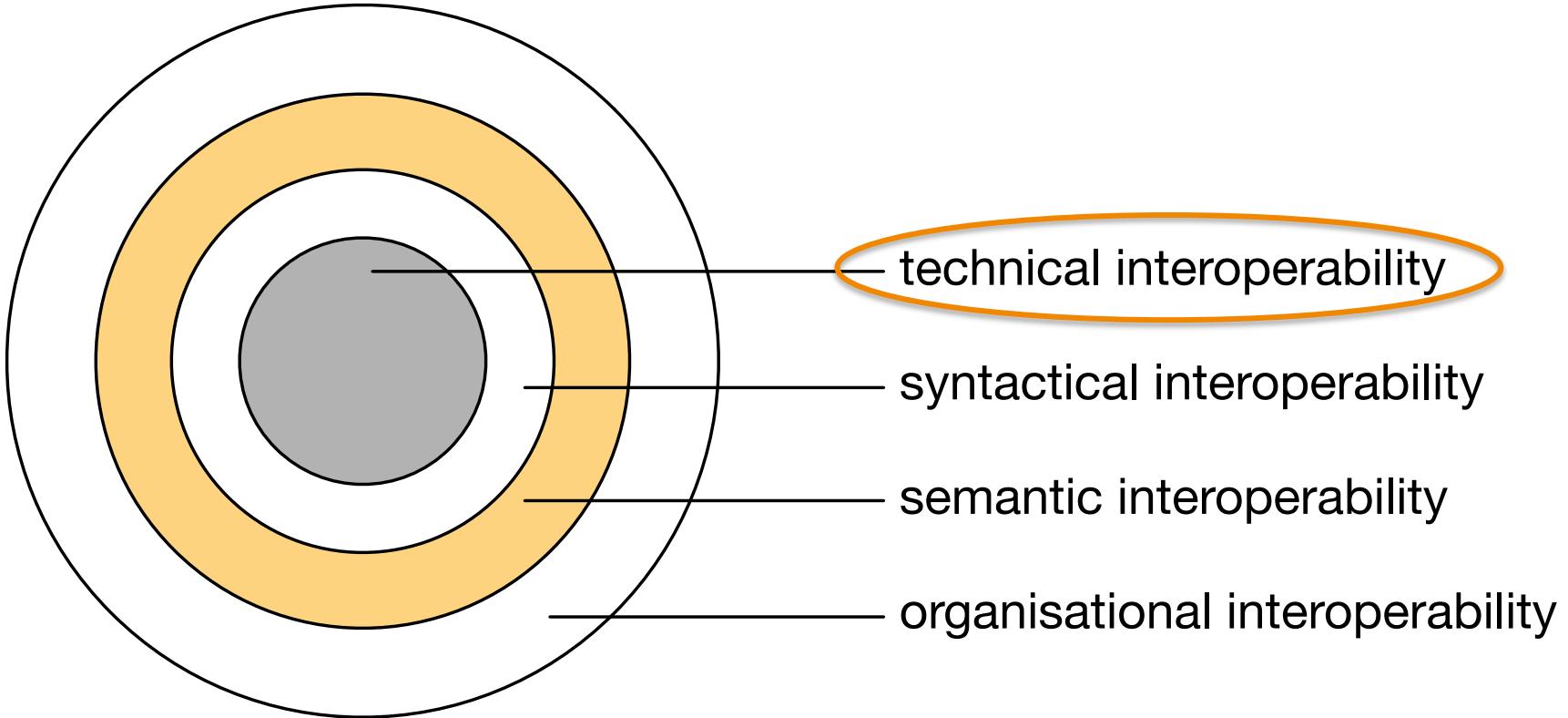
④

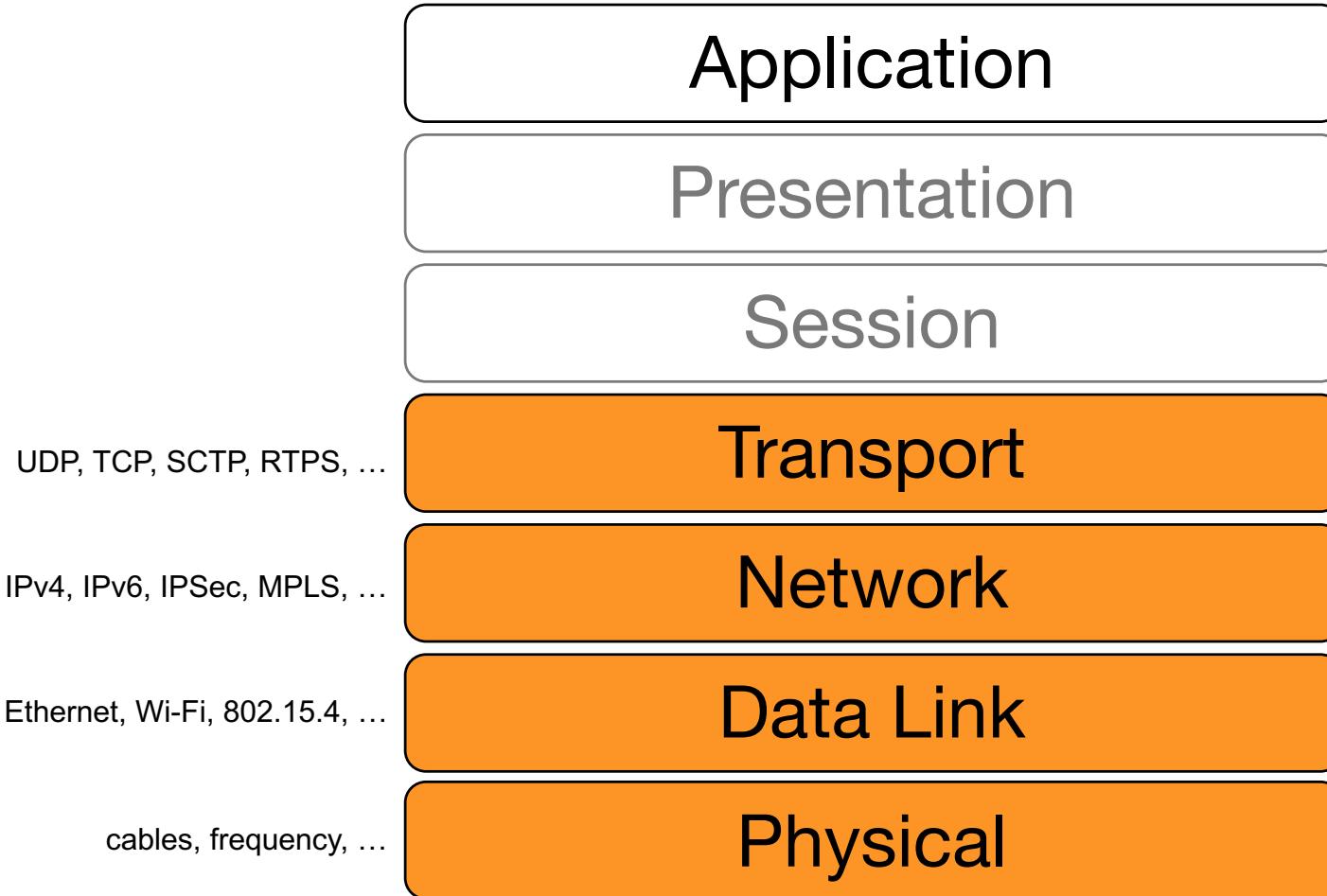
Programmability

# TERMINOLOGY

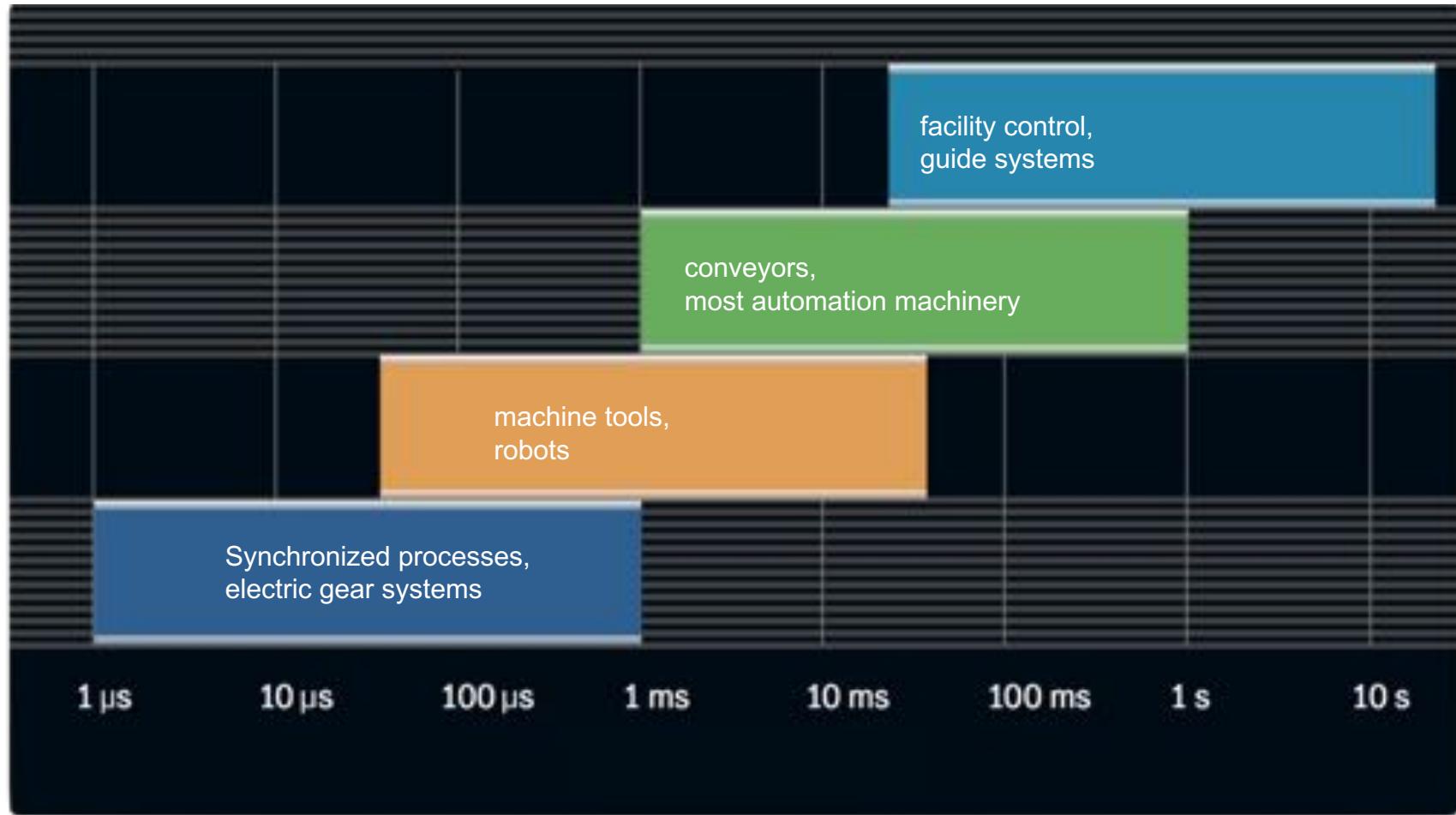


# DIFFERENT LEVELS OF INTEROPERABILITY

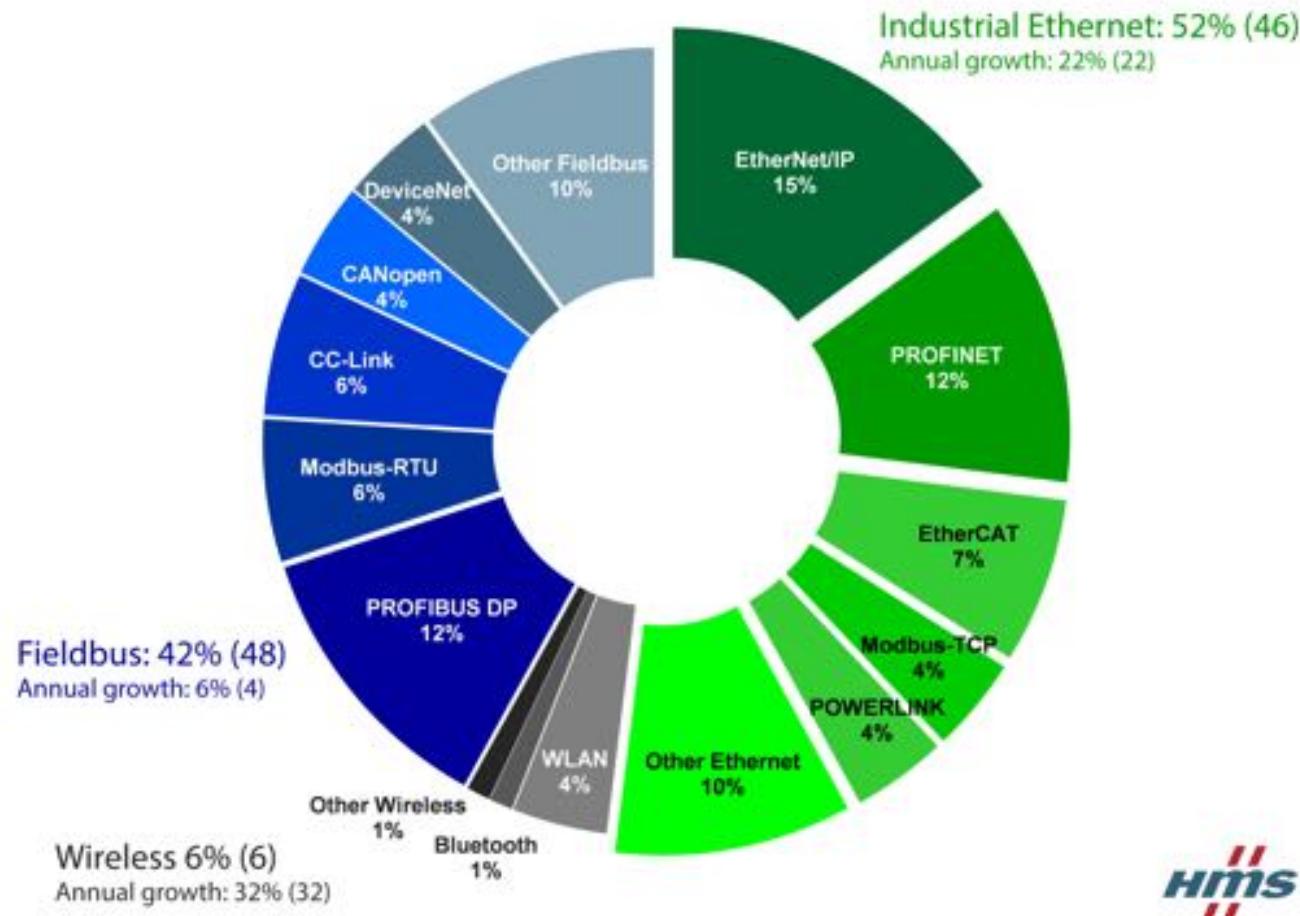




# REAL-TIME REQUIREMENTS



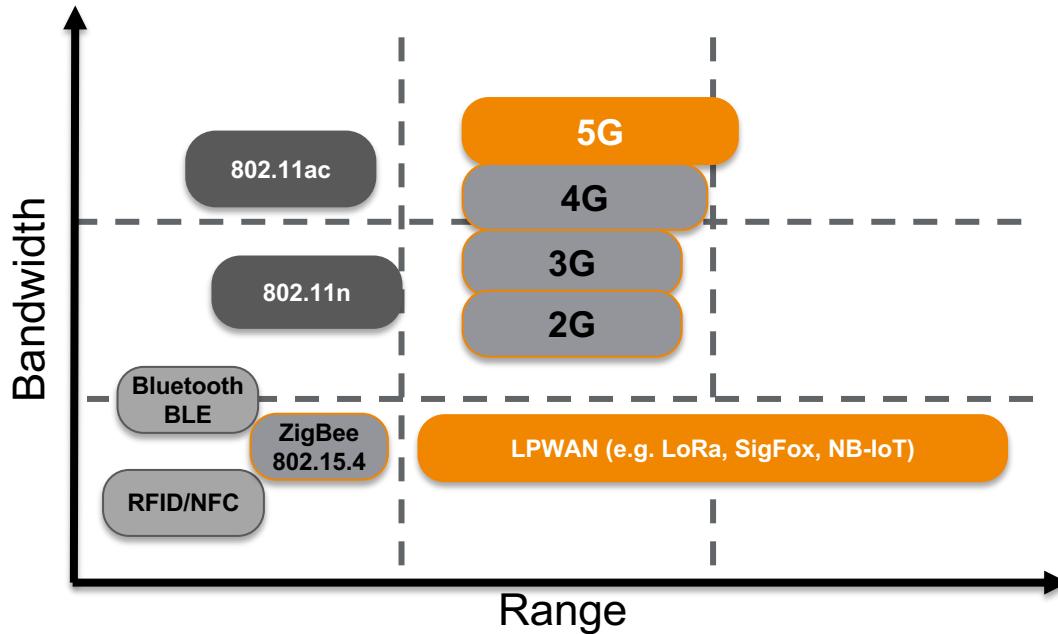
# INDUSTRIAL NETWORK MARKET SHARES 2018



HMS



# WIRELESS TECHNOLOGIES COMPARED



Source: <http://de.slideshare.net/PeterREgli/lpwan>

①

Connectivity

②

Communication

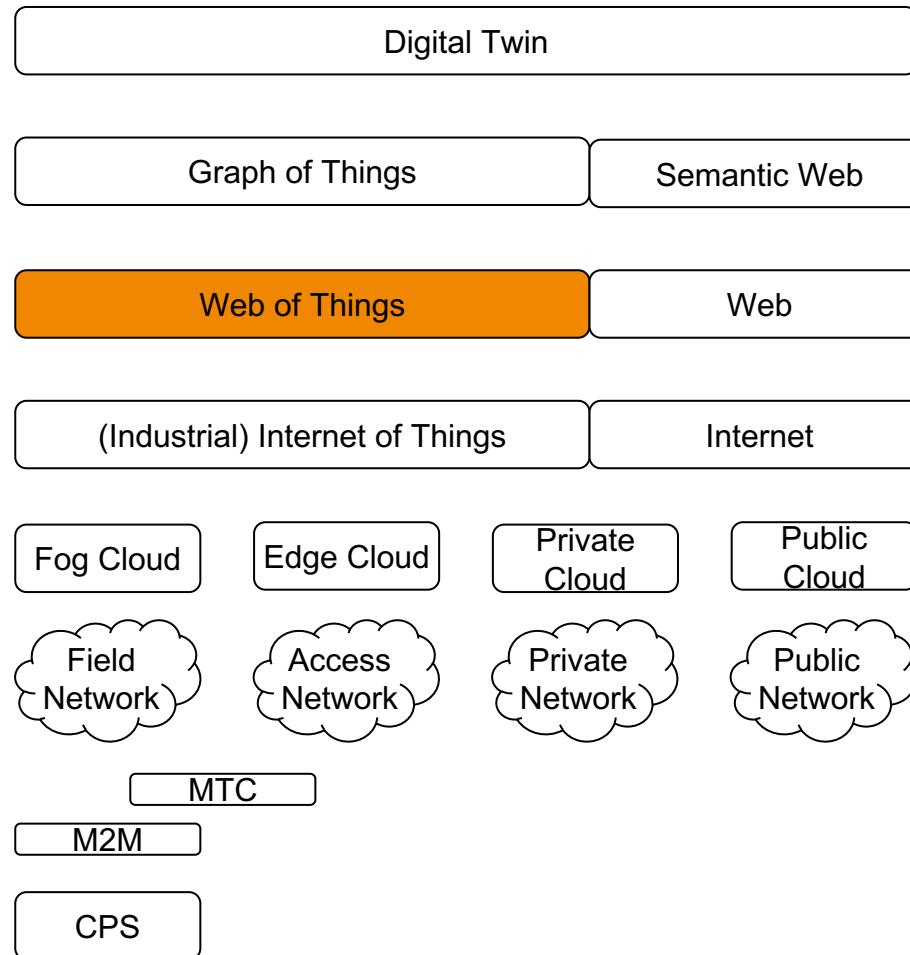
③

Interoperability

④

Programmability

# TERMINOLOGY



# COMMUNICATION

oneM2M API, OPC UA API, DDS API, ...

XML-RPC, SOAP, REST, ...

HTTP, AMQP, MQTT, CoAP, WS, ...

Middleware

Application

Presentation

Session

Transport

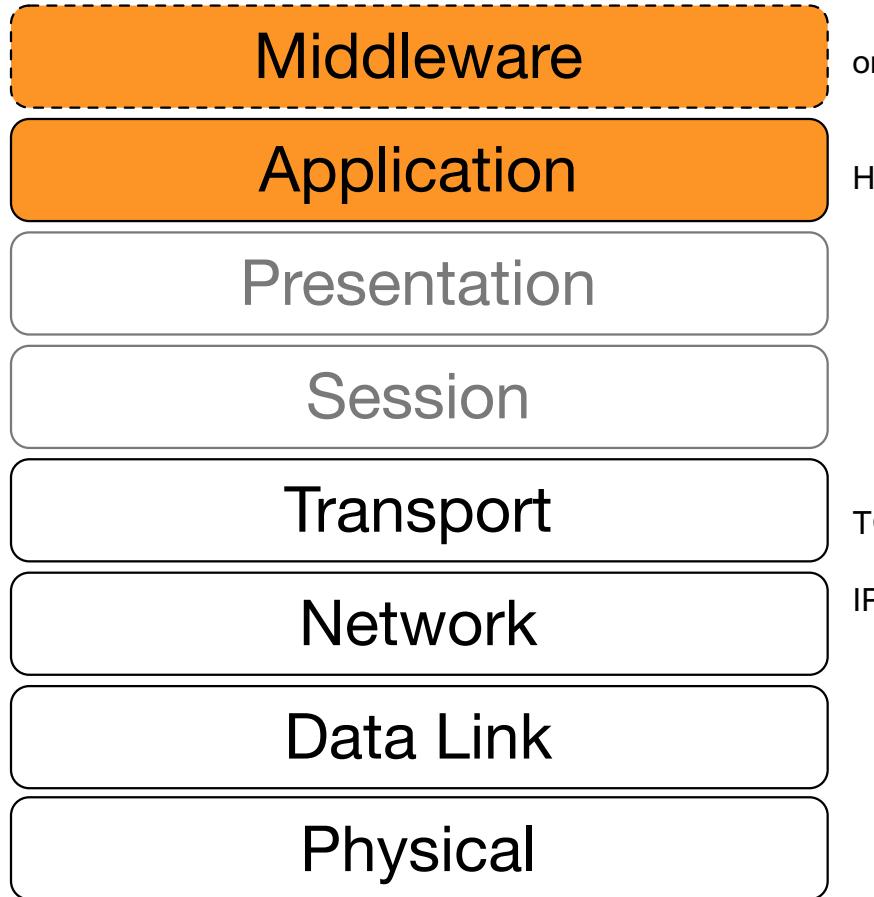
Network

Data Link

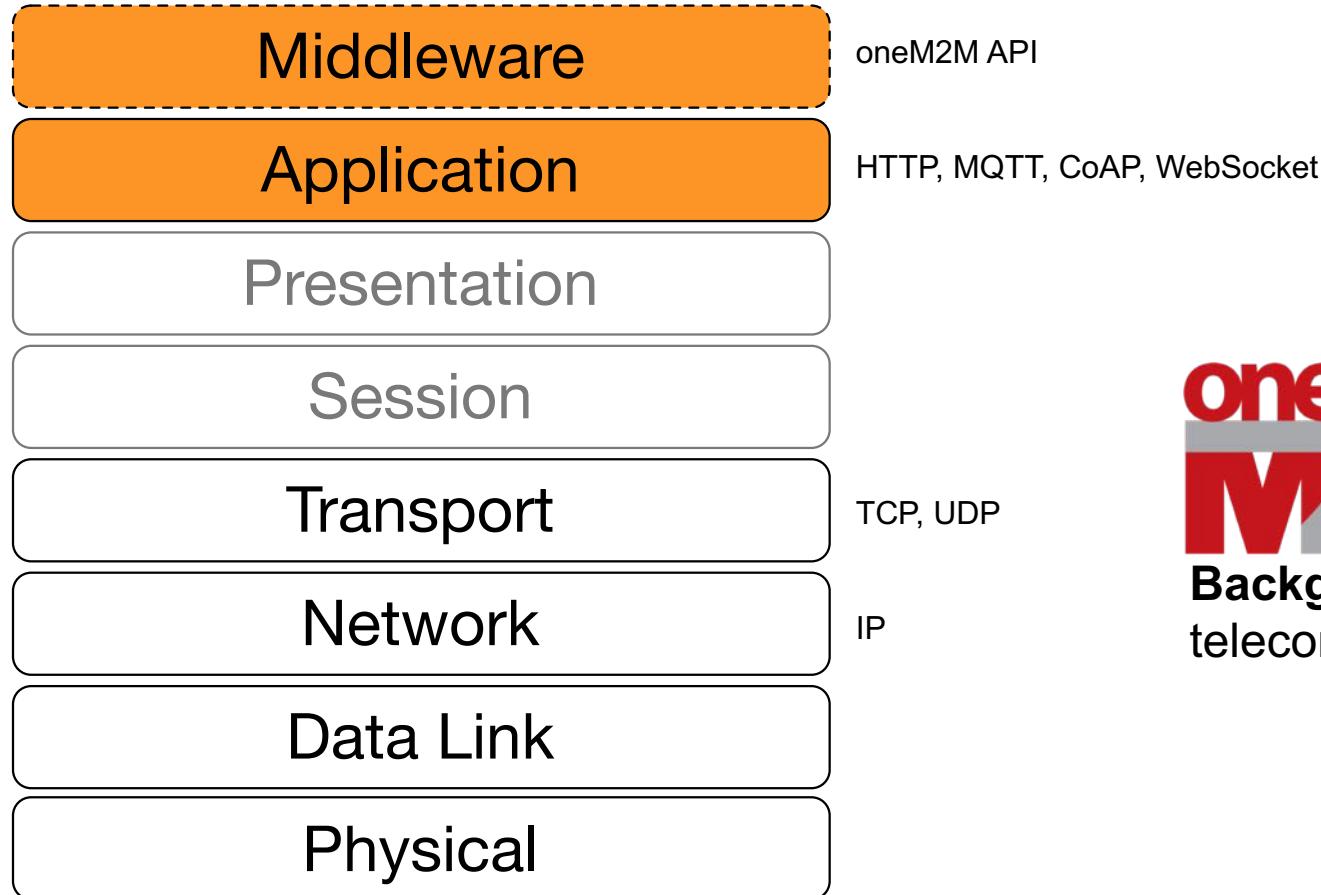
Physical

Open Systems Interconnection (OSI) Layers

# OPEN PLATFORM COMMUNICATIONS UNIFIED ARCHITECTURE



**Background:** Vertical automation industry



**Background:** Horizontal telecommunications industry

①

Connectivity

②

Communication

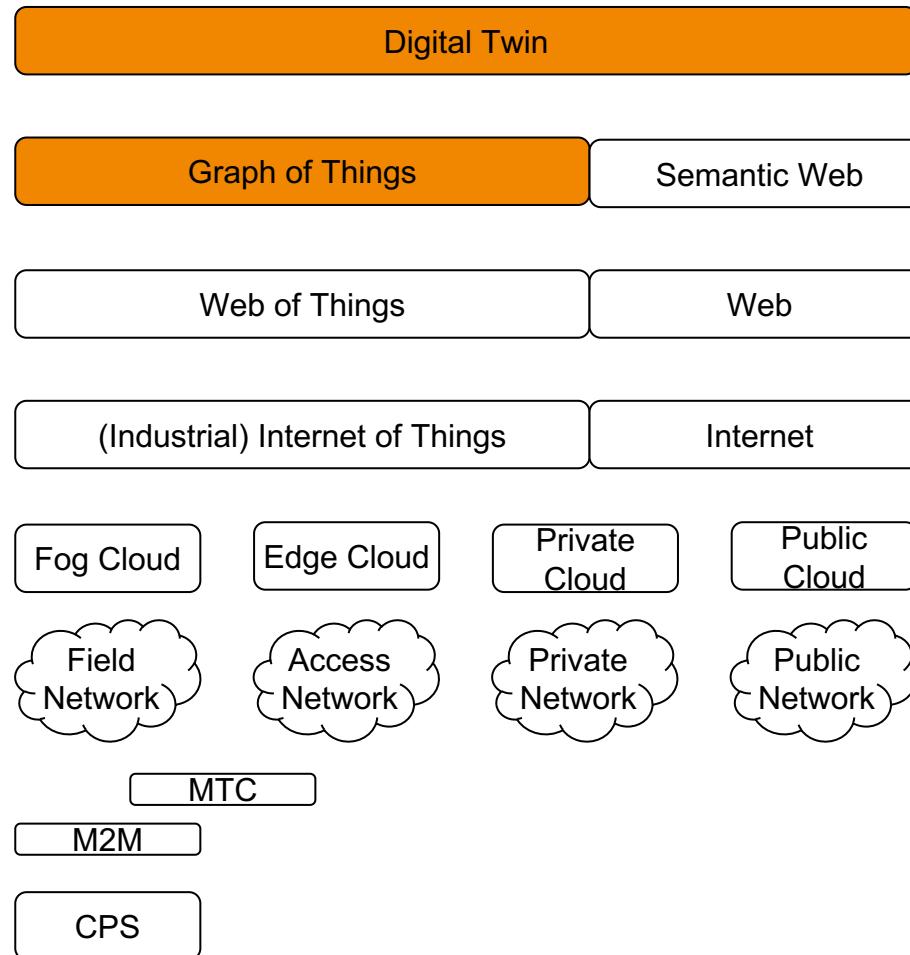
③

Data

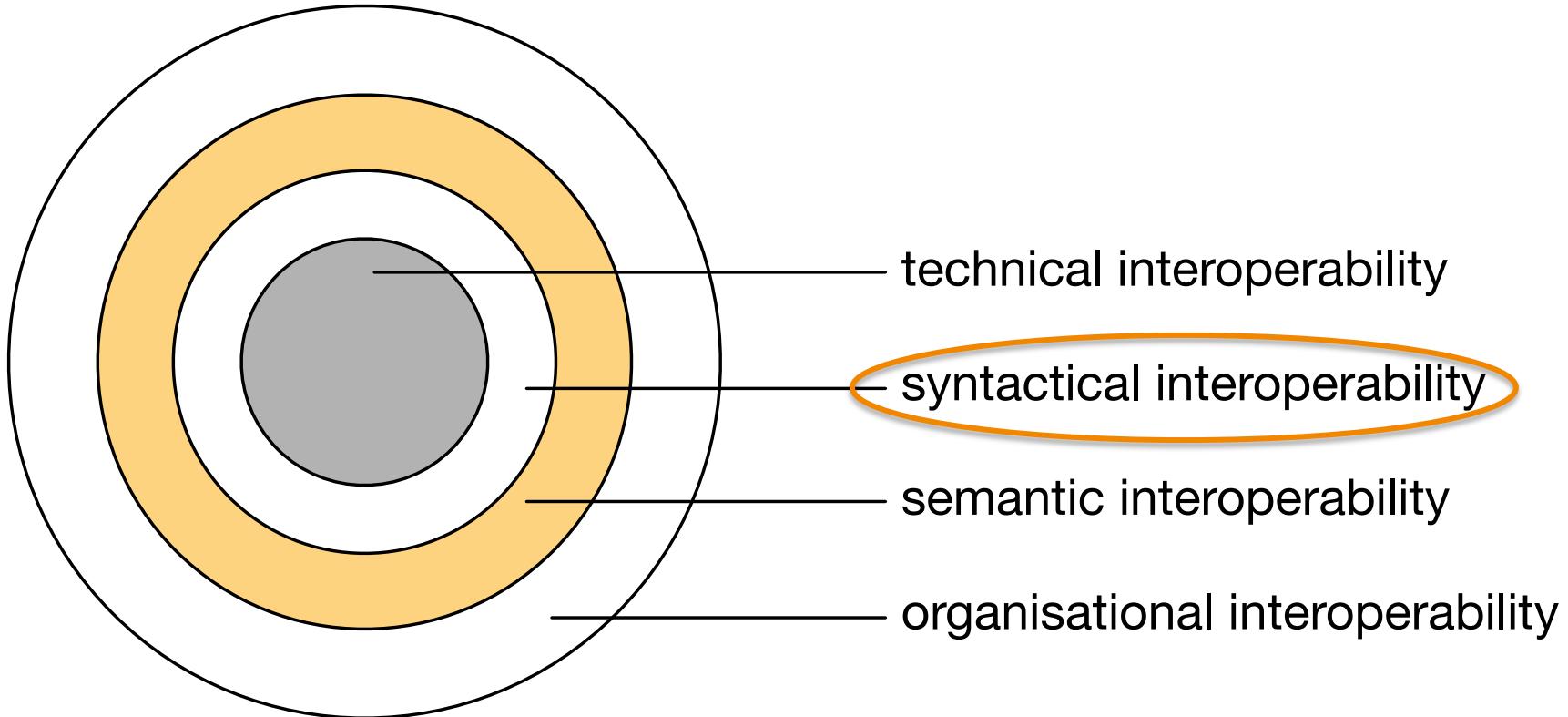
④

Programmability

# TERMINOLOGY

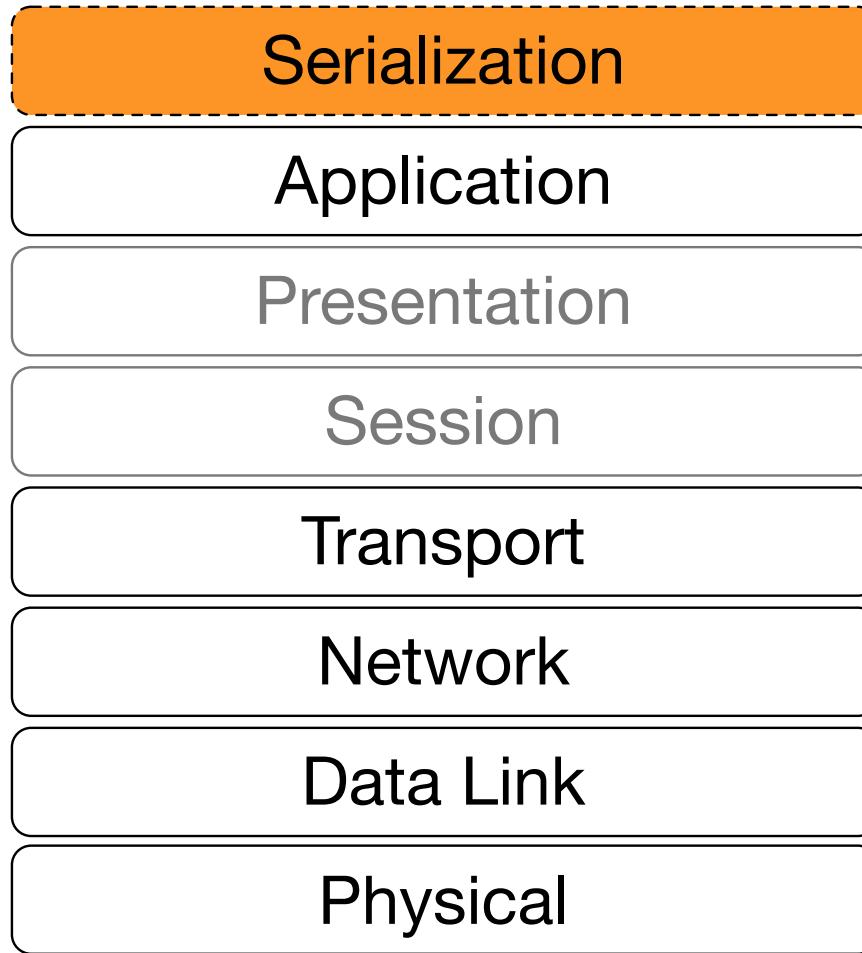


# DIFFERENT LEVELS OF INTEROPERABILITY



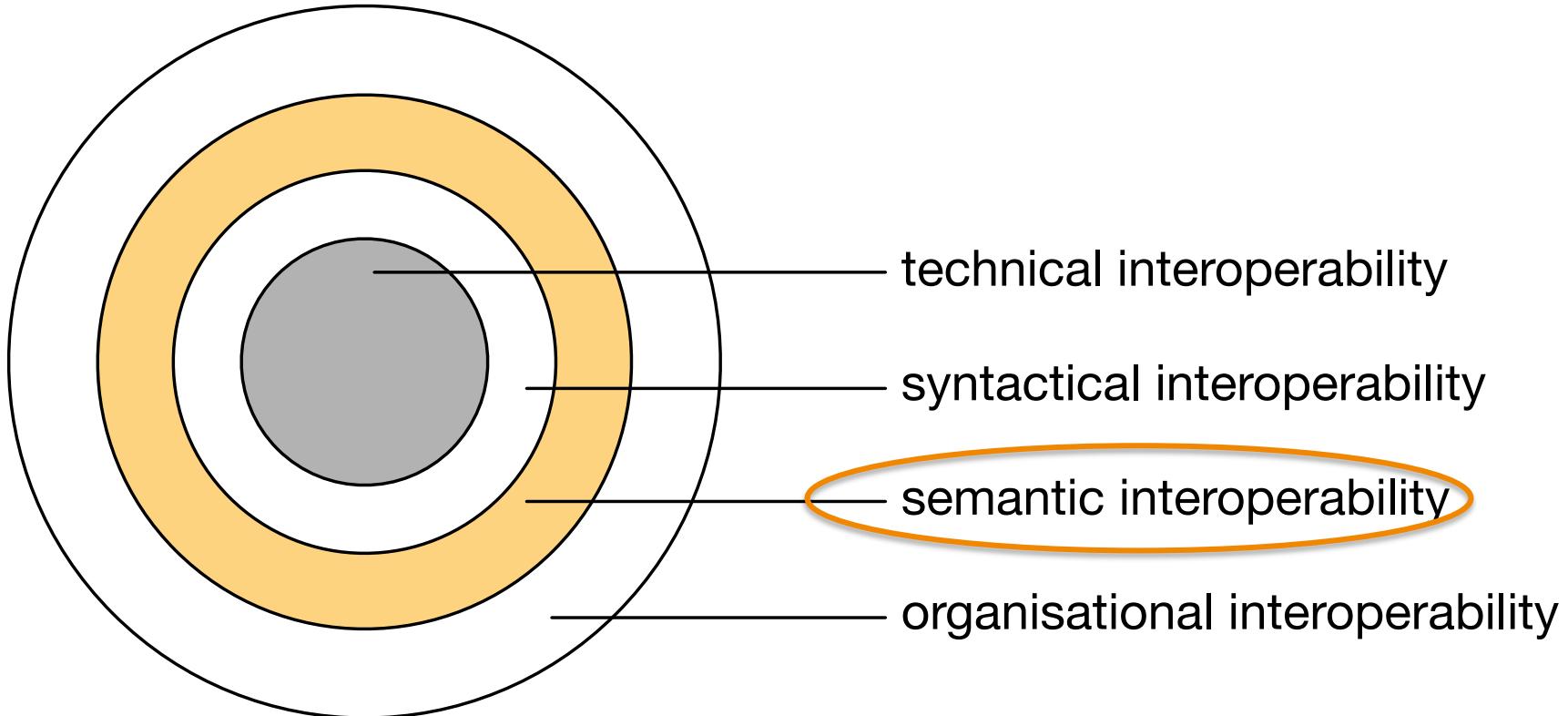
# SYNTACTICAL INTEROPERABILITY

XML, JSON, CSV, TTL, binary,  
...

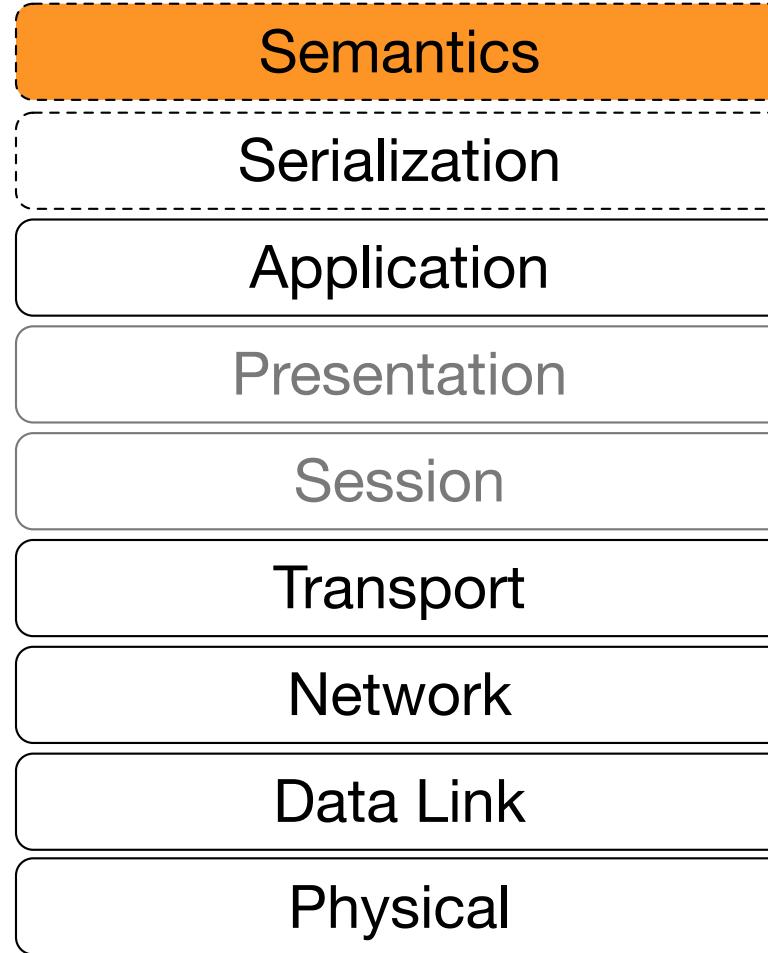


Open Systems Interconnection (OSI) Layers

# DIFFERENT LEVELS OF INTEROPERABILITY

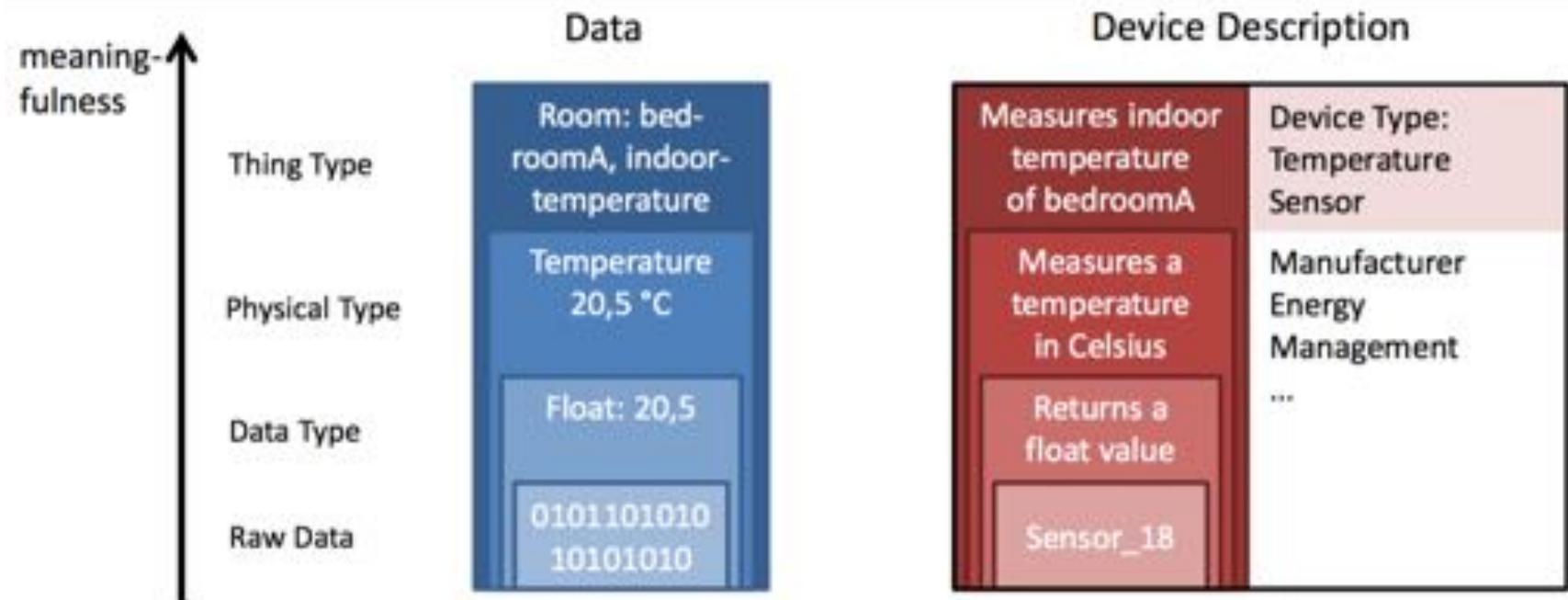


# SEMANTIC INTEROPERABILITY



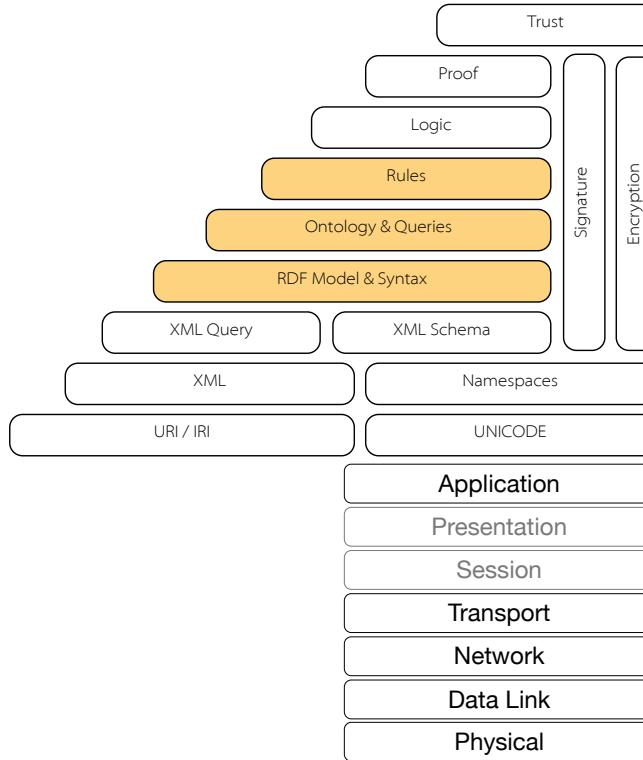
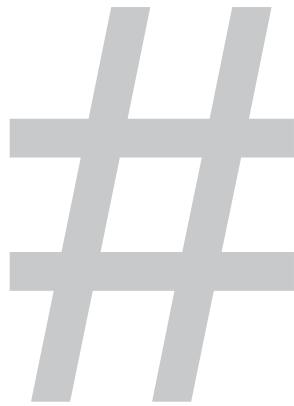
Open Systems Interconnection (OSI) Layers

# LEVELS OF MEANINGFULNESS



# USING THE SEMANTIC WEB LAYER CAKE

Based on T. Berners-Lee. *WWW Past and Future*. Presentation at the Royal Society, London.



①

Connectivity

②

Communication

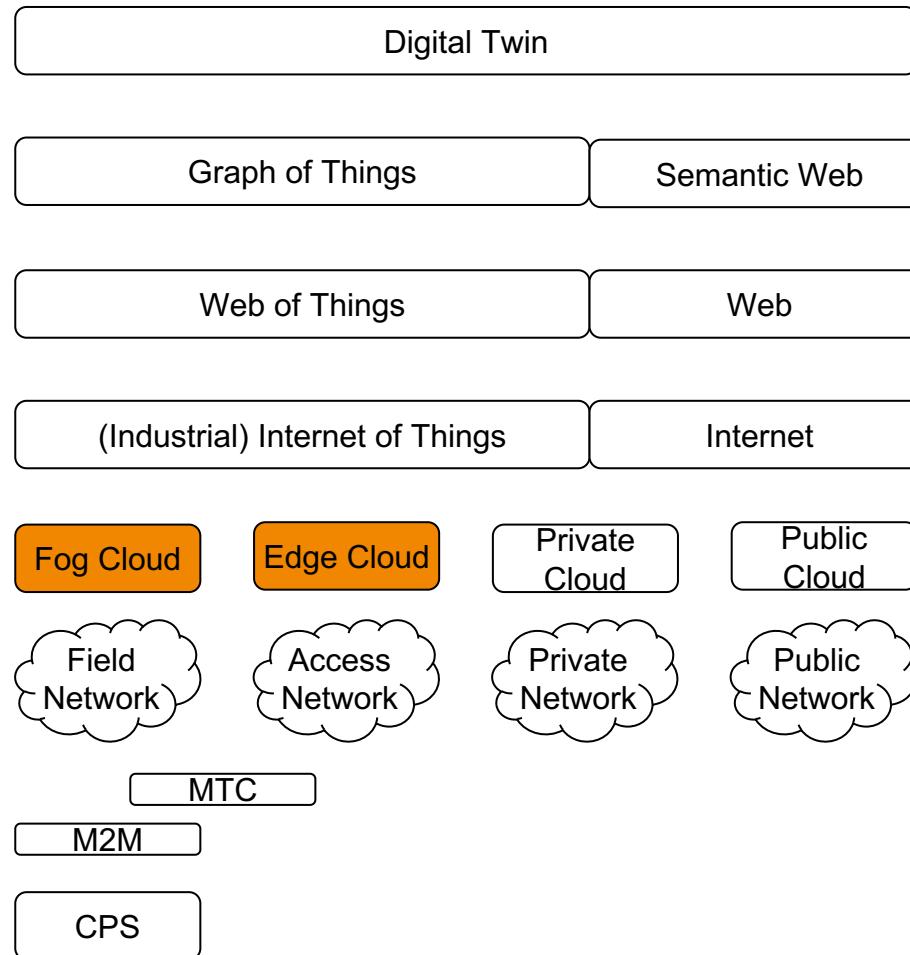
③

Data

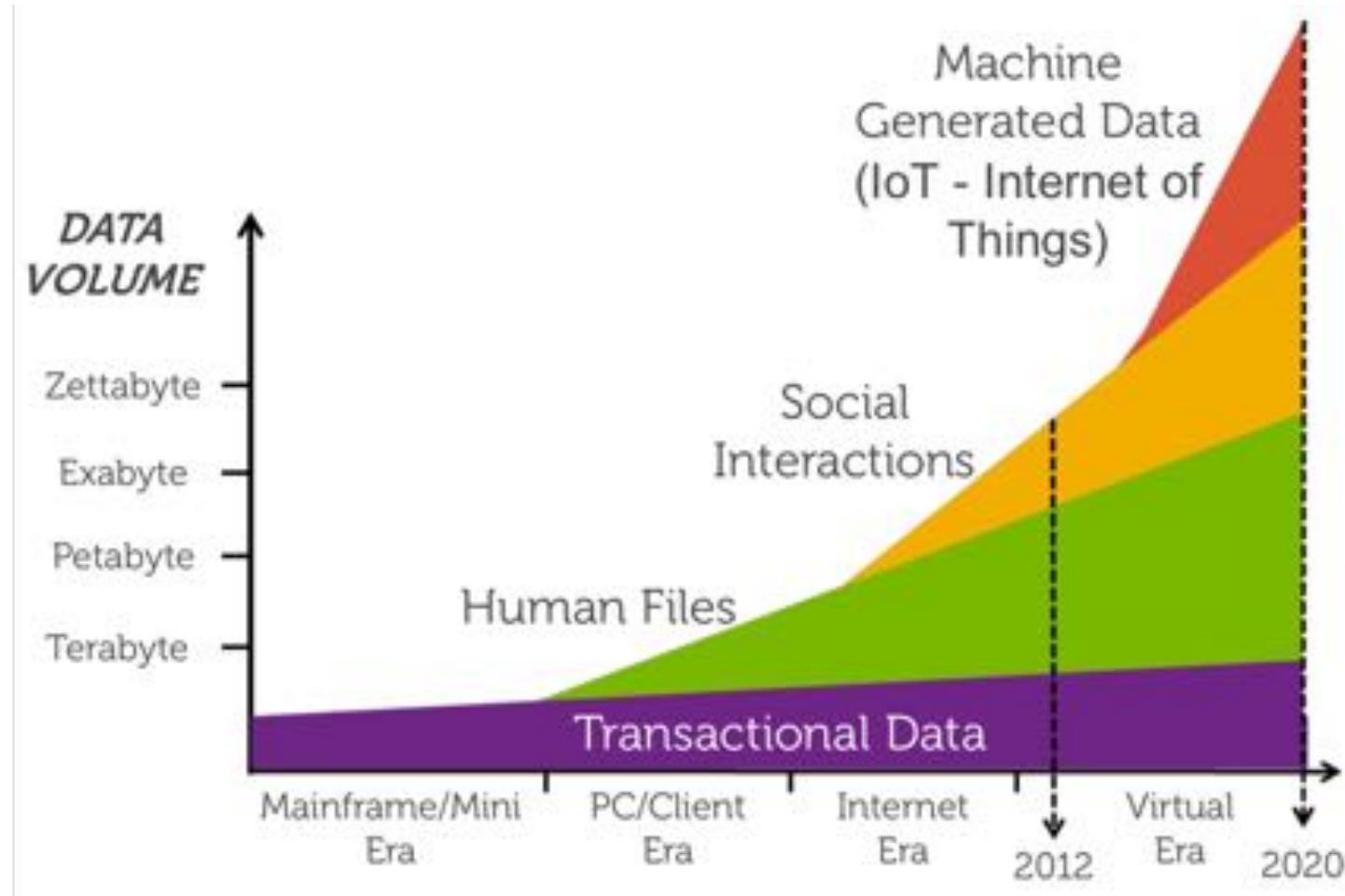
④

Programmability

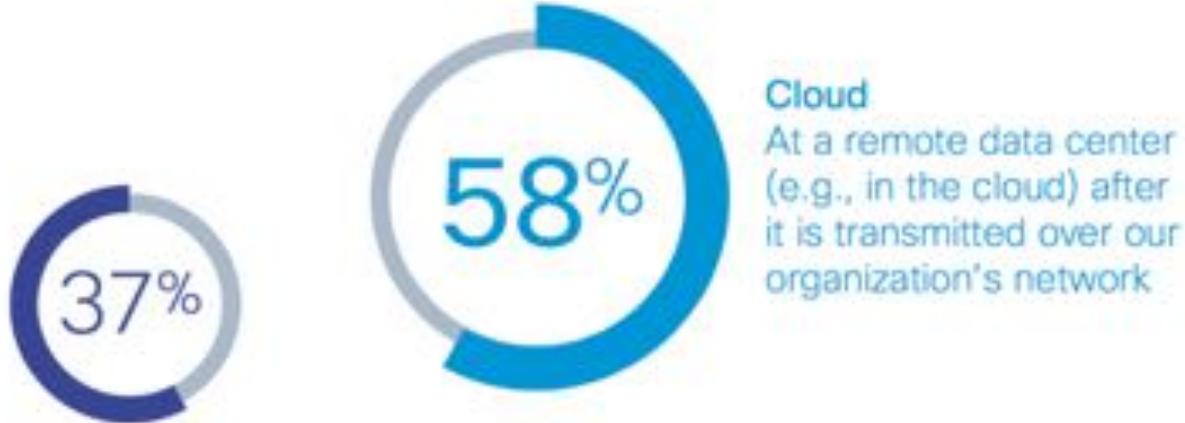
# TERMINOLOGY



BY 2020 THE DIGITAL UNIVERSE WILL REACH 44 TRILLION GB.



## WHERE DATA WILL BE PROCESSED UNTIL 2017



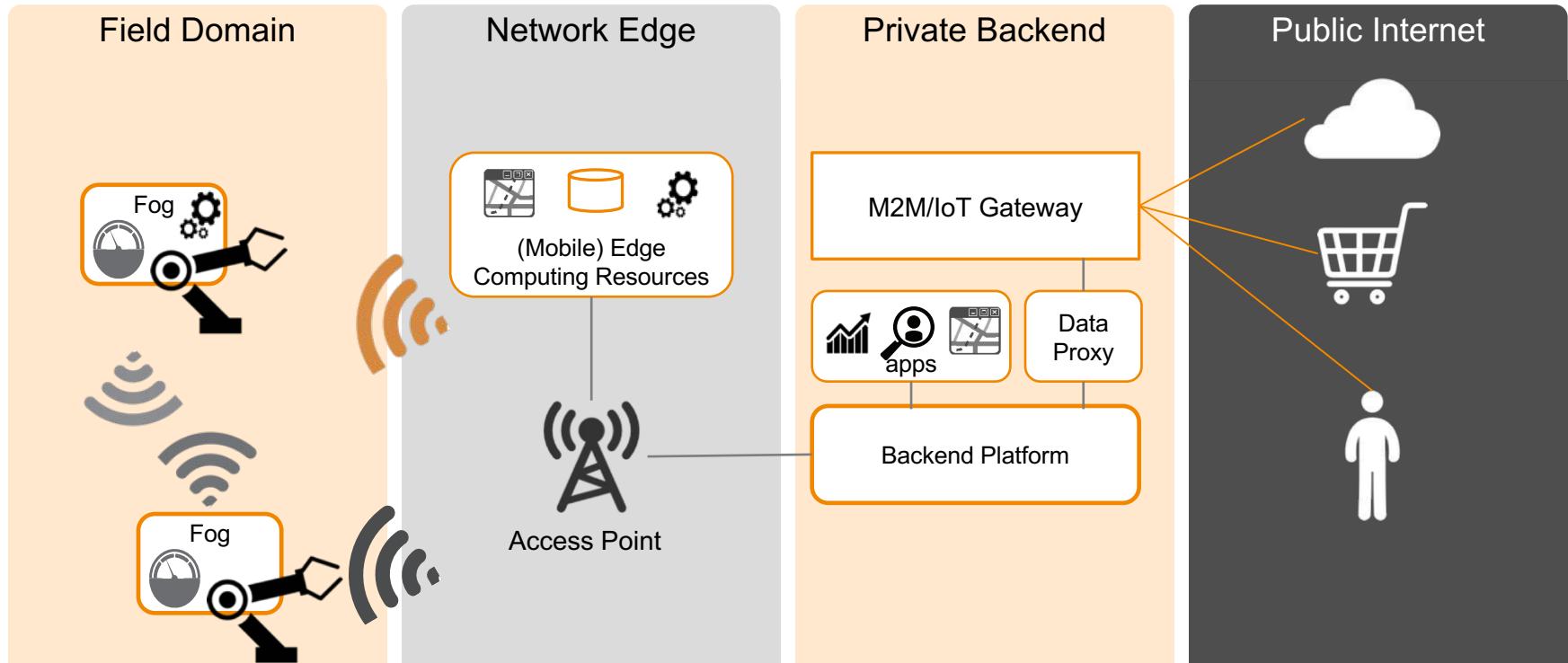
### Edge

At the "edge" of the network on smart devices (e.g., mobile devices, appliances, routers) located locally, near where the data is generated

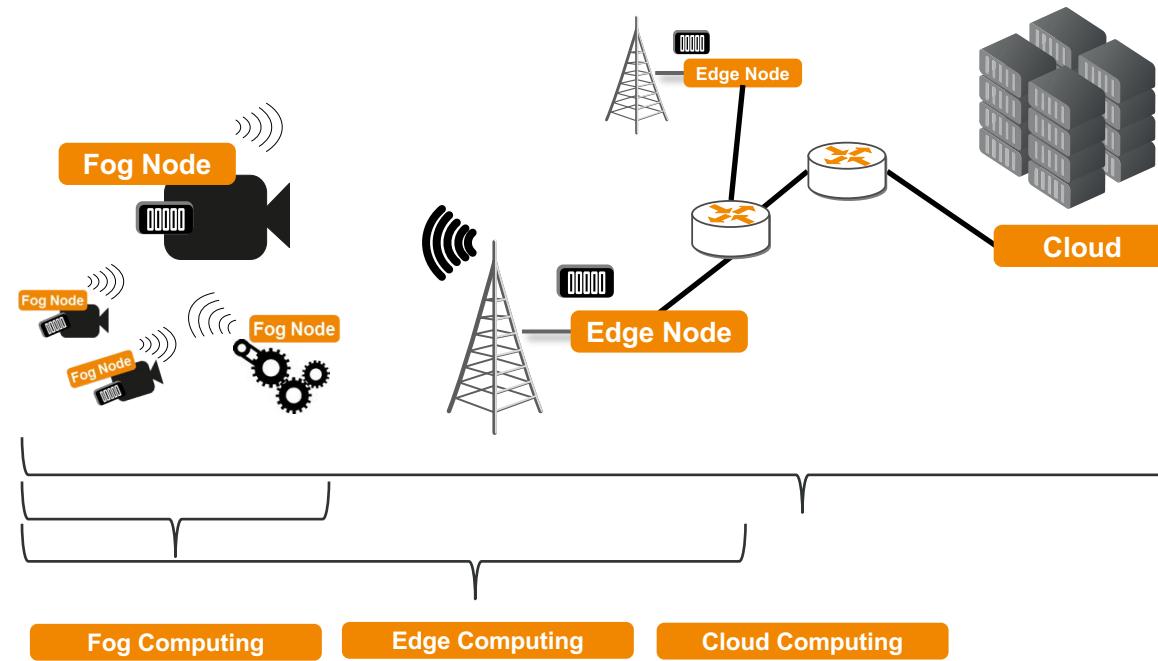


Three years from now, where will most data generated by IoT solutions be processed?

# FOG | EDGE | CLOUD | INTERCLOUD COMPUTING



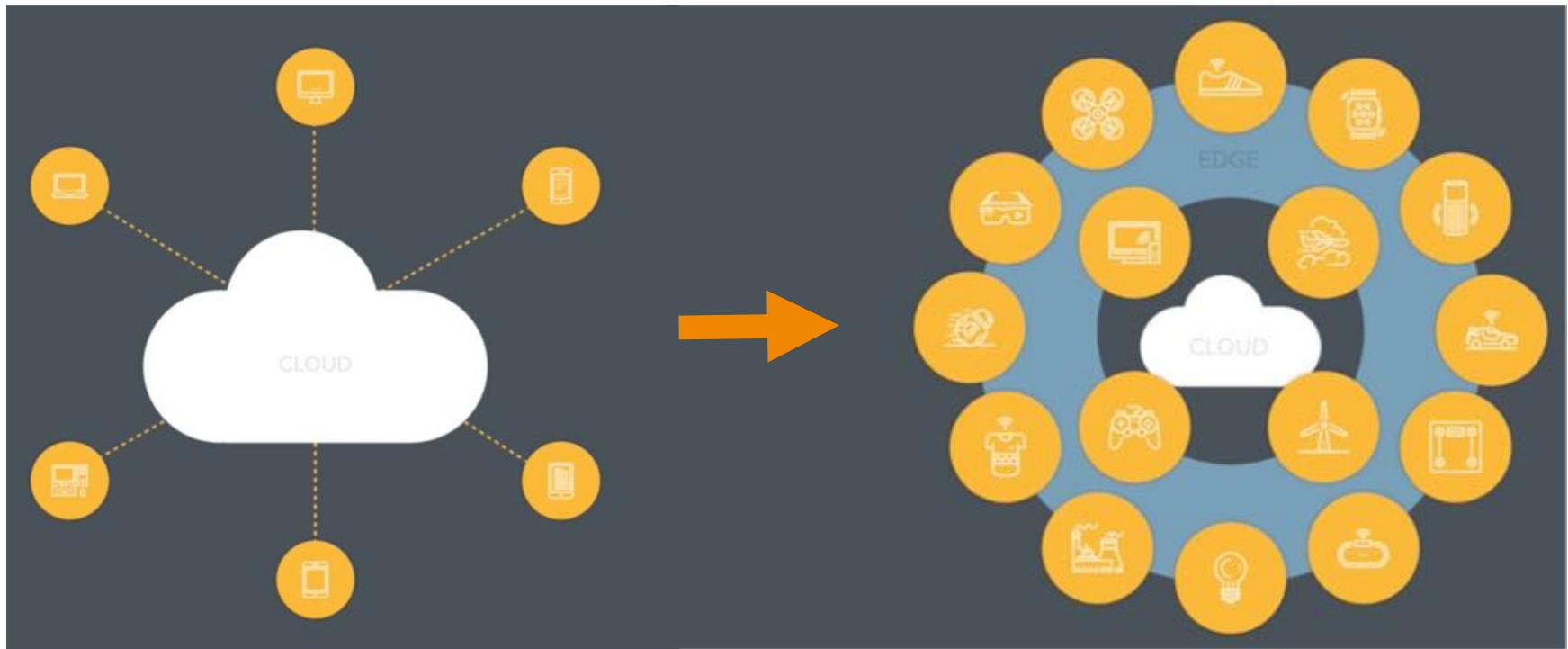
# TOWARDS INTEGRATED FOG, EDGE AND CLOUD COMPUTING



# BACK TO THE FUTURE



# FROM CENTRAL CLOUDS TO PEER-TO-PEER FOG CLOUDS



## **THE IIOT LECTURE**

Register at ISIS: <http://av.tu-berlin.de/teaching>

Register for a seminar/project topic: announced on ISIS

Send us a mail: [edu.org@av.tu-berlin.de](mailto:edu.org@av.tu-berlin.de)