

Day 2

The Internet of Things Stack

BUSINESS MODEL CANVAS

KEY PARTNERS Who are your key partners?	KEY ACTIVITIES What are the activities you perform every day to deliver your value proposition?	VALUE PROPOSITION What is the value you deliver to your customer? What is the customer need that your value proposition addresses?	CUSTOMER RELATIONSHIPS What relationship does each customer segment expect you to establish and maintain?	CUSTOMER SEGMENTS Who are your customers?
	KEY RESOURCES What are the resources you need to deliver your value proposition?		CHANNELS How do your customer segments want to be reached?	
COST STRUCTURE What are the important costs you make to deliver the value proposition?		REVENUE STREAMS How do customers reward you for the value you provide to them?		



DESIGNED BY **BUSINESS MODEL FOUNDRY AG**

This work is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License.
<http://creativecommons.org/licenses/by-sa/4.0/> or send a letter to Creative Commons,
171 Second Street, Suite 300, San Francisco, California, 94105, USA.



My classes (2 of 4)

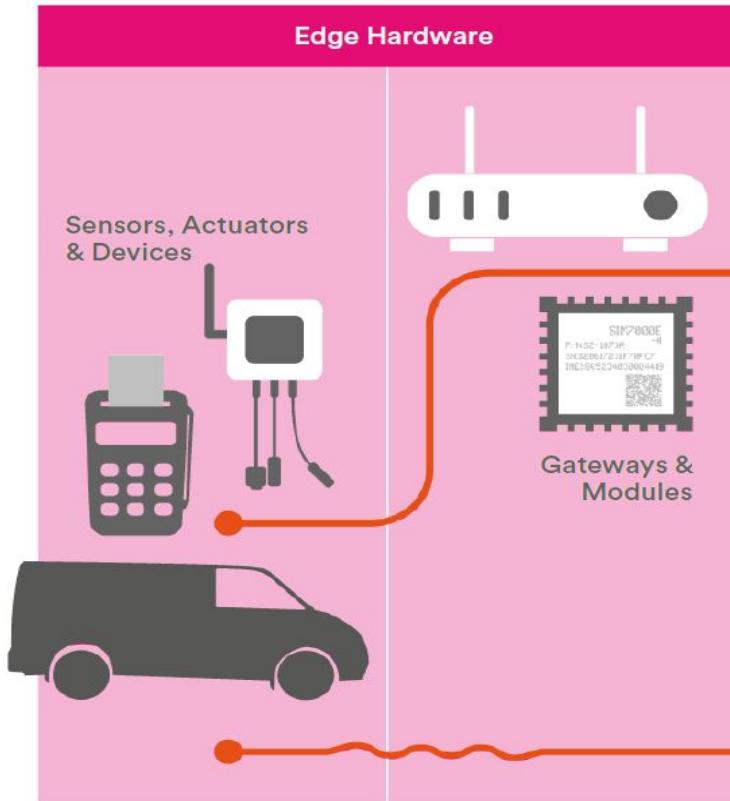
- ~~Business models and the Internet of Things.~~
- ~~Business Model Canvas~~
- How to build your IoT project, digital transformation and more.
- IoT Model Canvas
- Edge Computing, Edge AI and others.
- Let's build a project together
- Examples and demos

Today

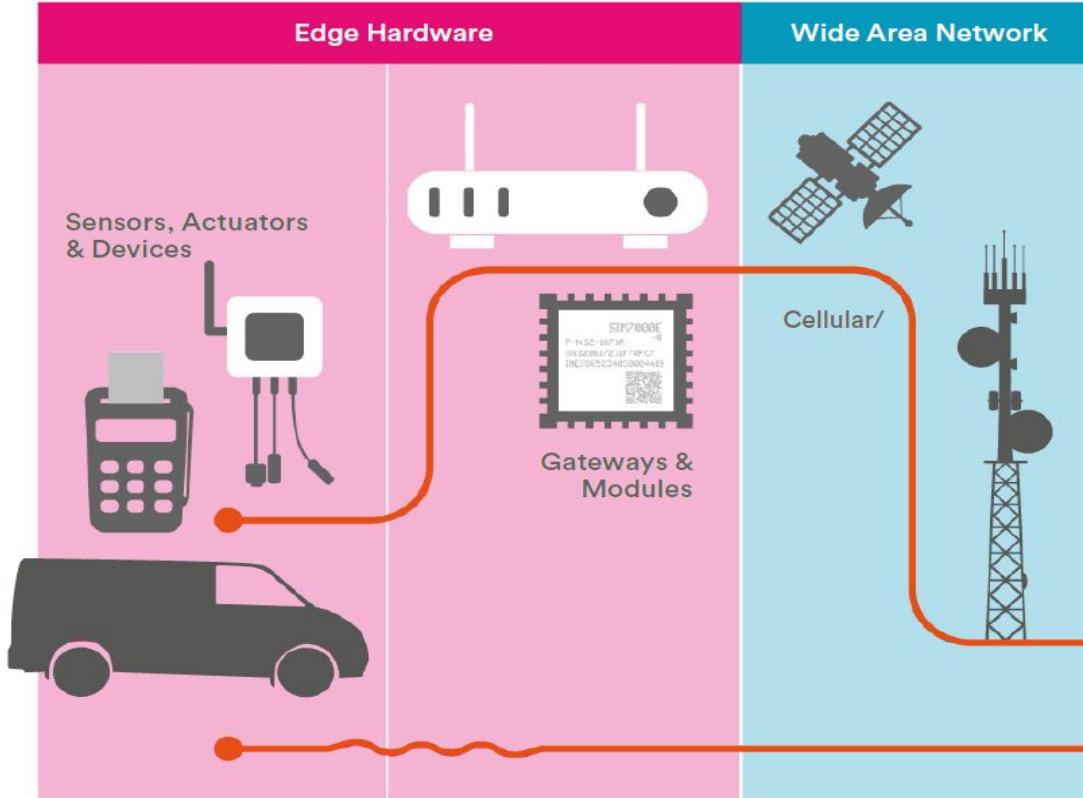
- How to build your IoT solution
- The IoT Stack
- IoT Model Canvas
- The Industrial IoT Use Case

What do you need to build an IoT Solution?

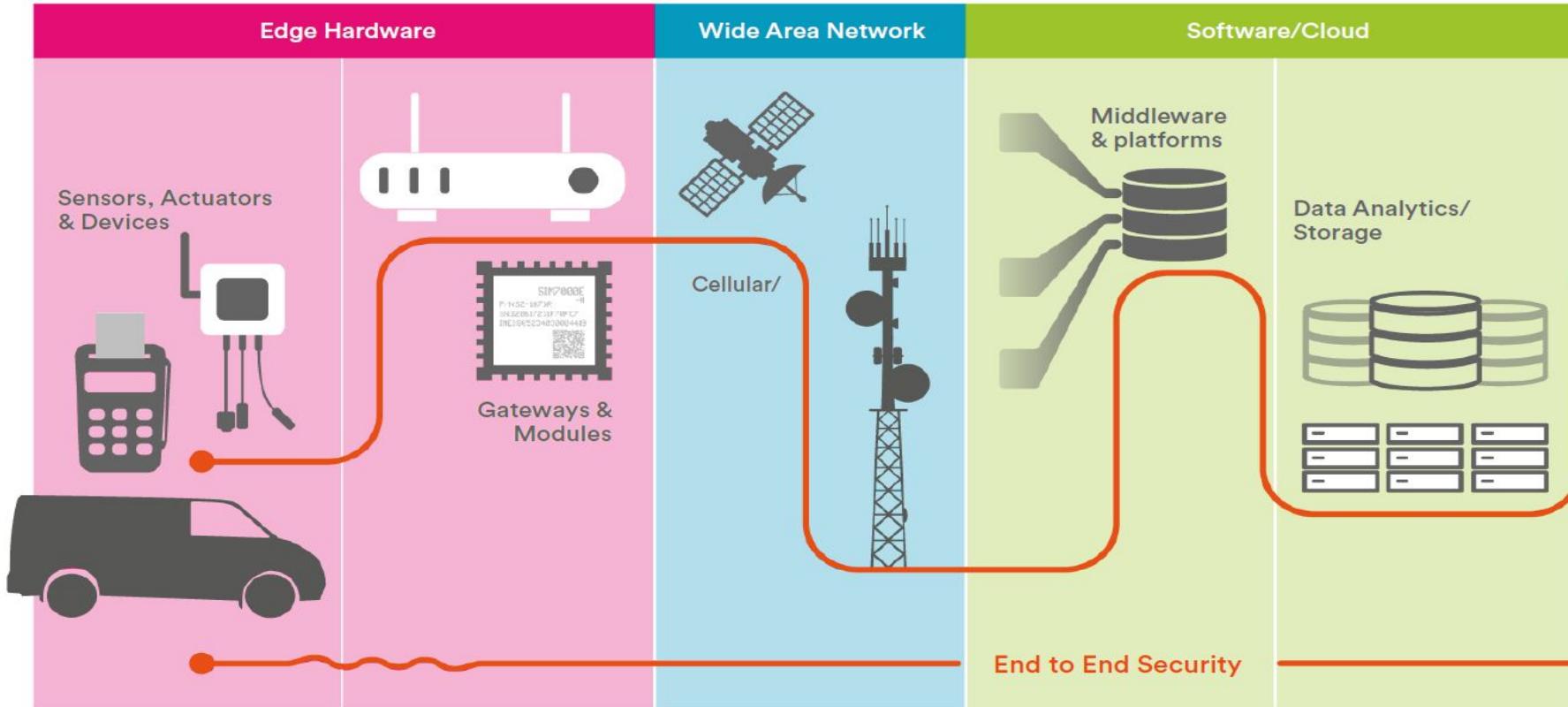
What do you need to build an IoT Solution?



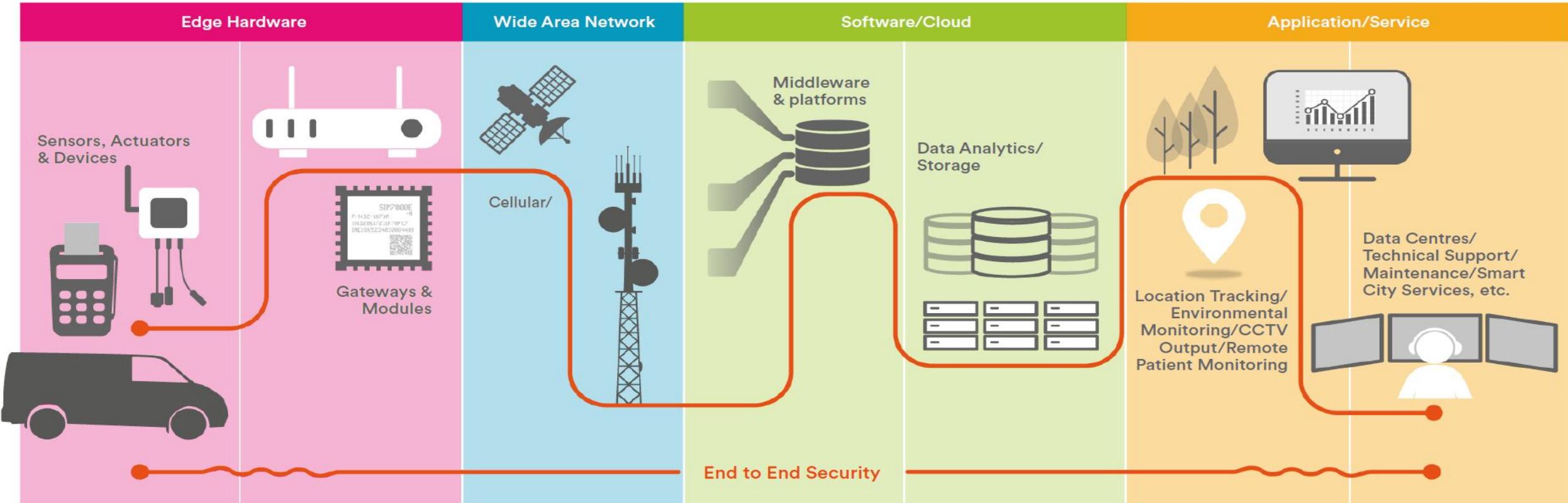
What do you need to build an IoT Solution?



What do you need to build an IoT Solution?

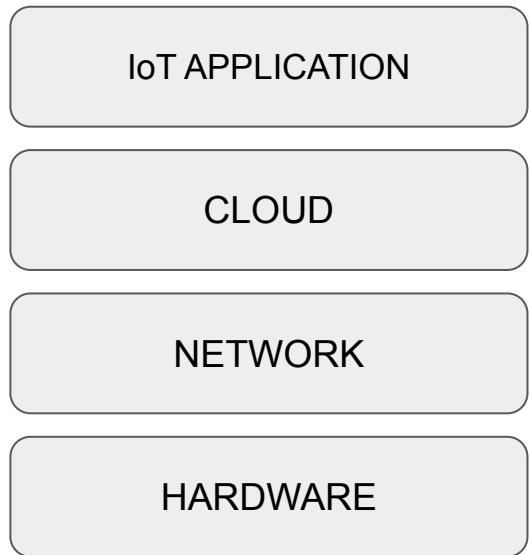


What do you need to build an IoT Solution?

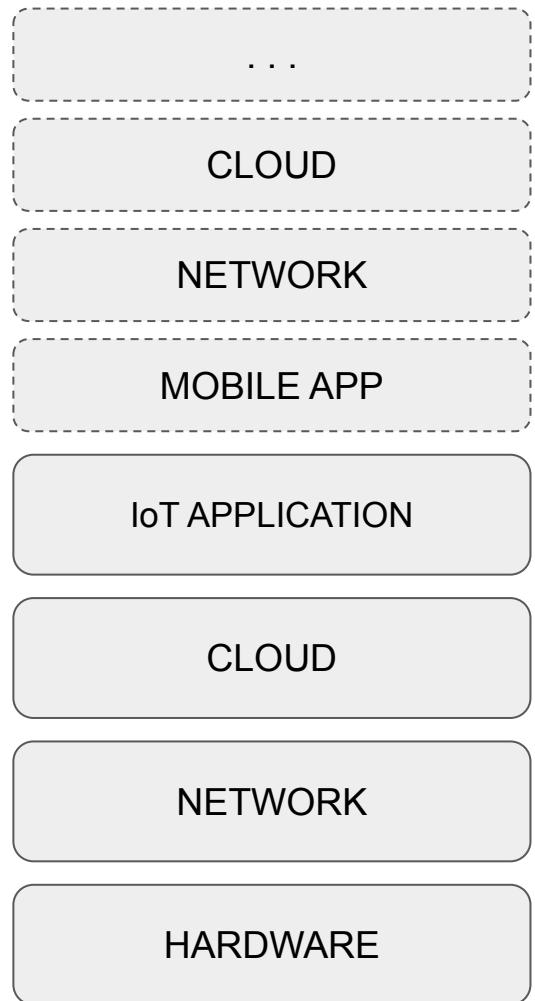


The IoT Stack

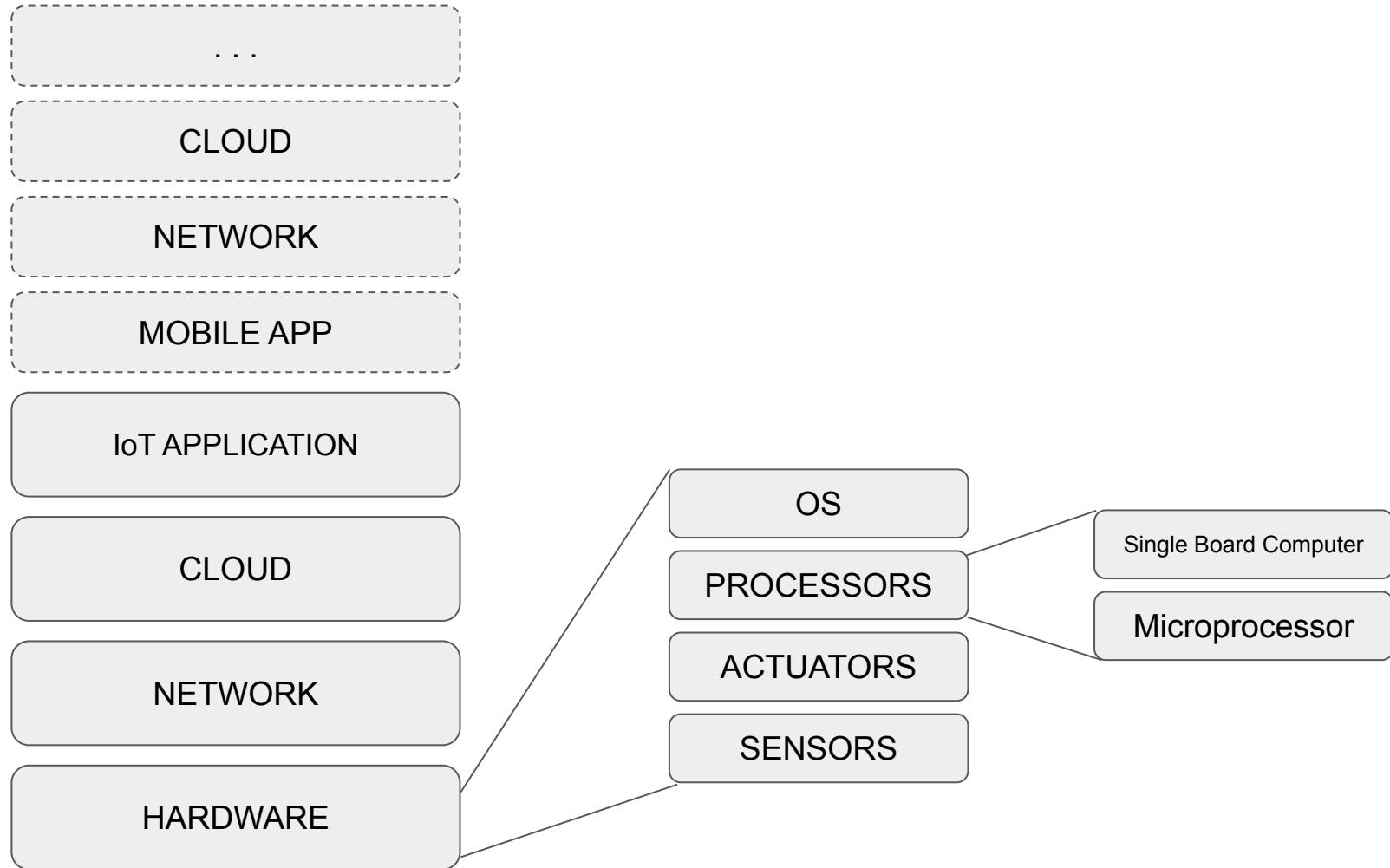
The IoT Stack



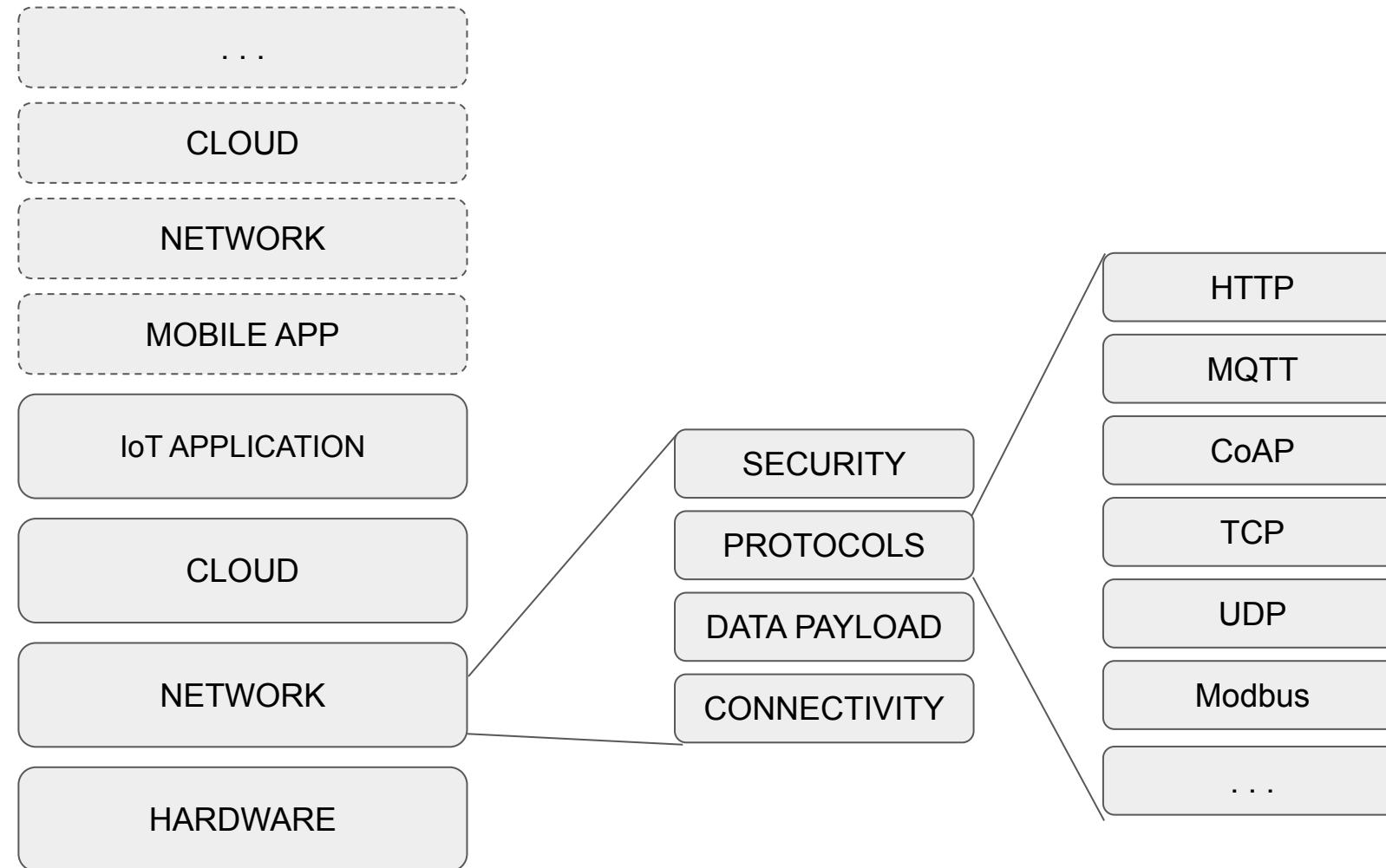
The IoT Stack



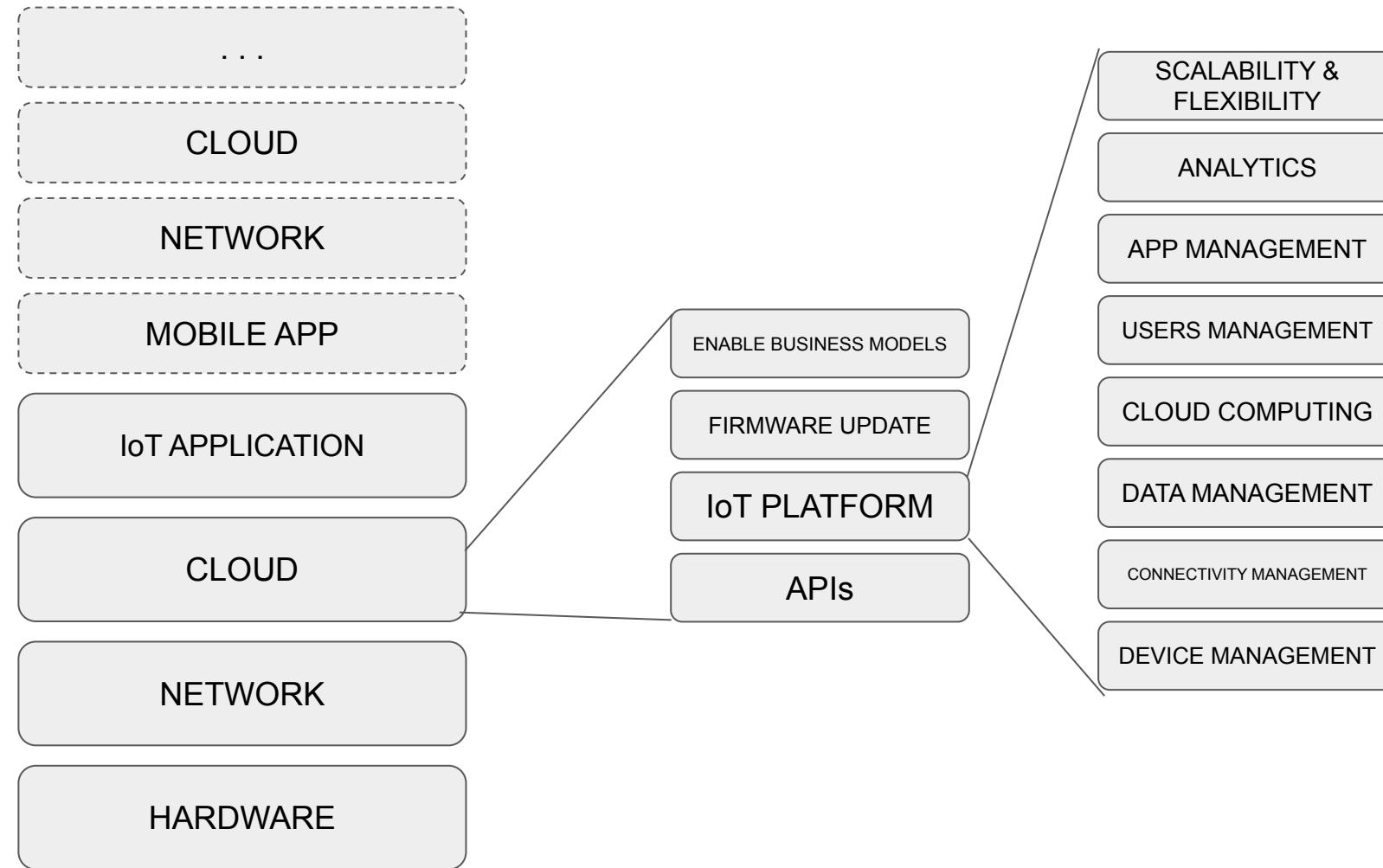
The IoT Stack



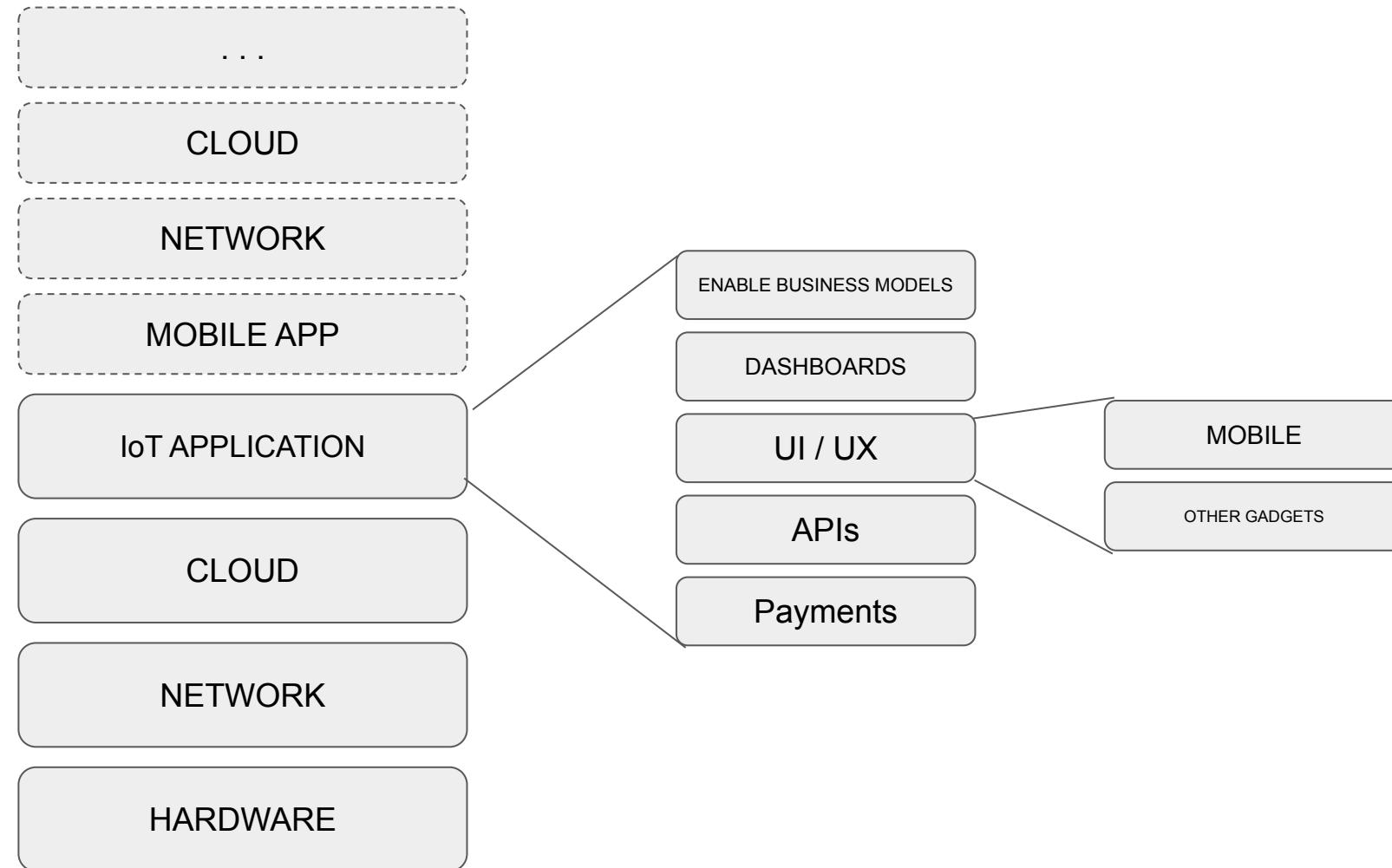
The IoT Stack



The IoT Stack



The IoT Stack

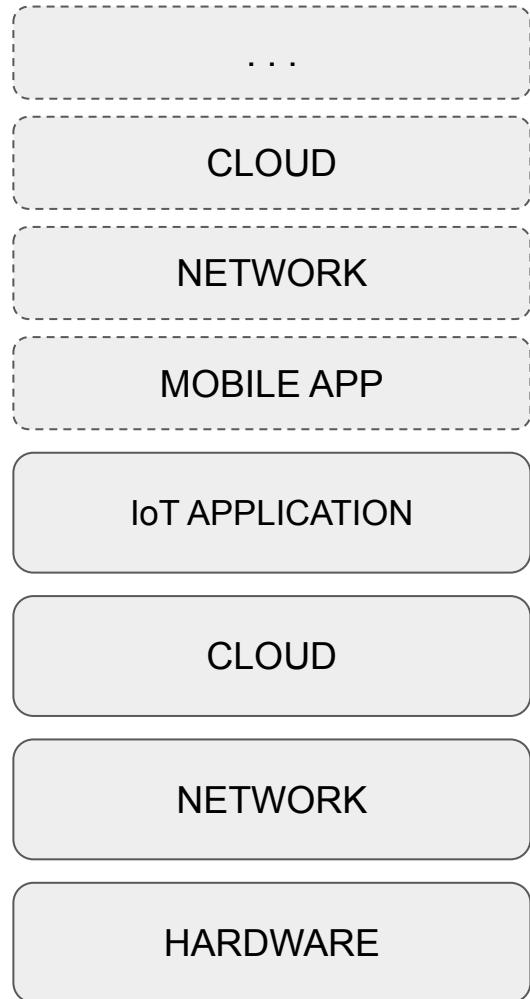


But still remember about the IoT definition...

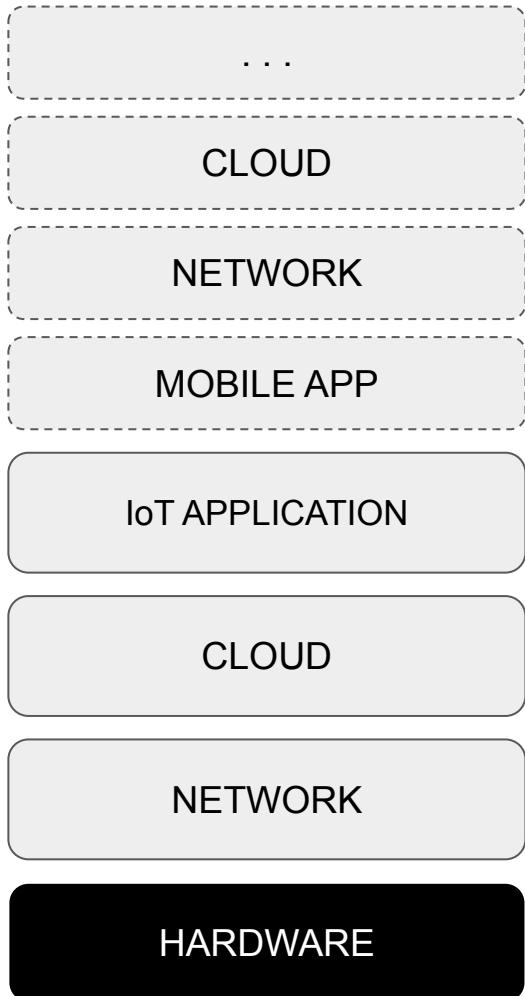
A close-up photograph of a man with light brown hair, wearing a white shirt. He is shouting into a black cordless telephone receiver held to his ear with his right hand. His mouth is wide open, showing his teeth. A large, white, speech bubble with a black outline originates from his mouth, containing the text "SHOW ME THE MONEY!" in bold, black, capital letters.

**SHOW
ME THE
MONEY!**

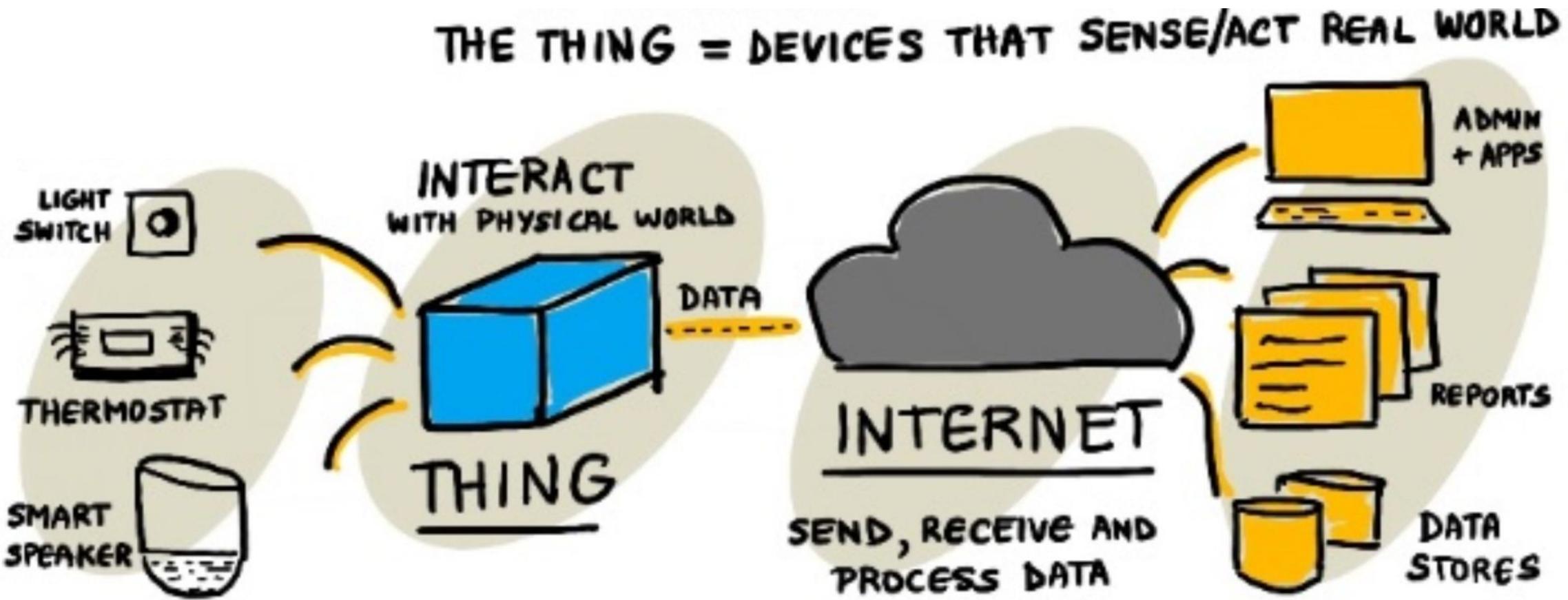
The IoT Stack (Zoom In)



The IoT Stack (Zoom In)



The hardware



The hardware

COMMUNICATION

SOFTWARE

DEVICE

The hardware

COMMUNICATION

SOFTWARE

OS

DRIVERS

NETWORK

RUNTIME

APP

REMOTE MANAGEMENT

PROCESSOR

SENSORS

ACTUATORS

DEVICE

Processors

Processors

- How much processing power do you need?
- How much storage do you need?
- How many sensors do you need to read?
- Do you need real-time control?
- Does your application run in the edge? (e.g. perform analytics on the edge, Machine Learning, etc.)
- Do you have enough processing power to support future software upgrade / releases?
- Do you have space constraints?
- Are we running on batteries?
- Do you need to perform AI (Floating point operations?)

Processors

MICROCONTROLLER

A microcontroller is a small computer with low-memory and programmable input / output peripherals.

- Can't run a complete operating system (e.g. freertos)
- Don't have the amount of computing power and resources.
- Run just one program repeatedly.

Examples

- <https://www.arduino.cc/>
- <https://www.espressif.com/en/products/socs/esp32>
- <https://www.st.com/en/microcontrollers-microprocessors/stm32-32-bit-arm-cortex-mcus.html>

SINGLE BOARD COMPUTER

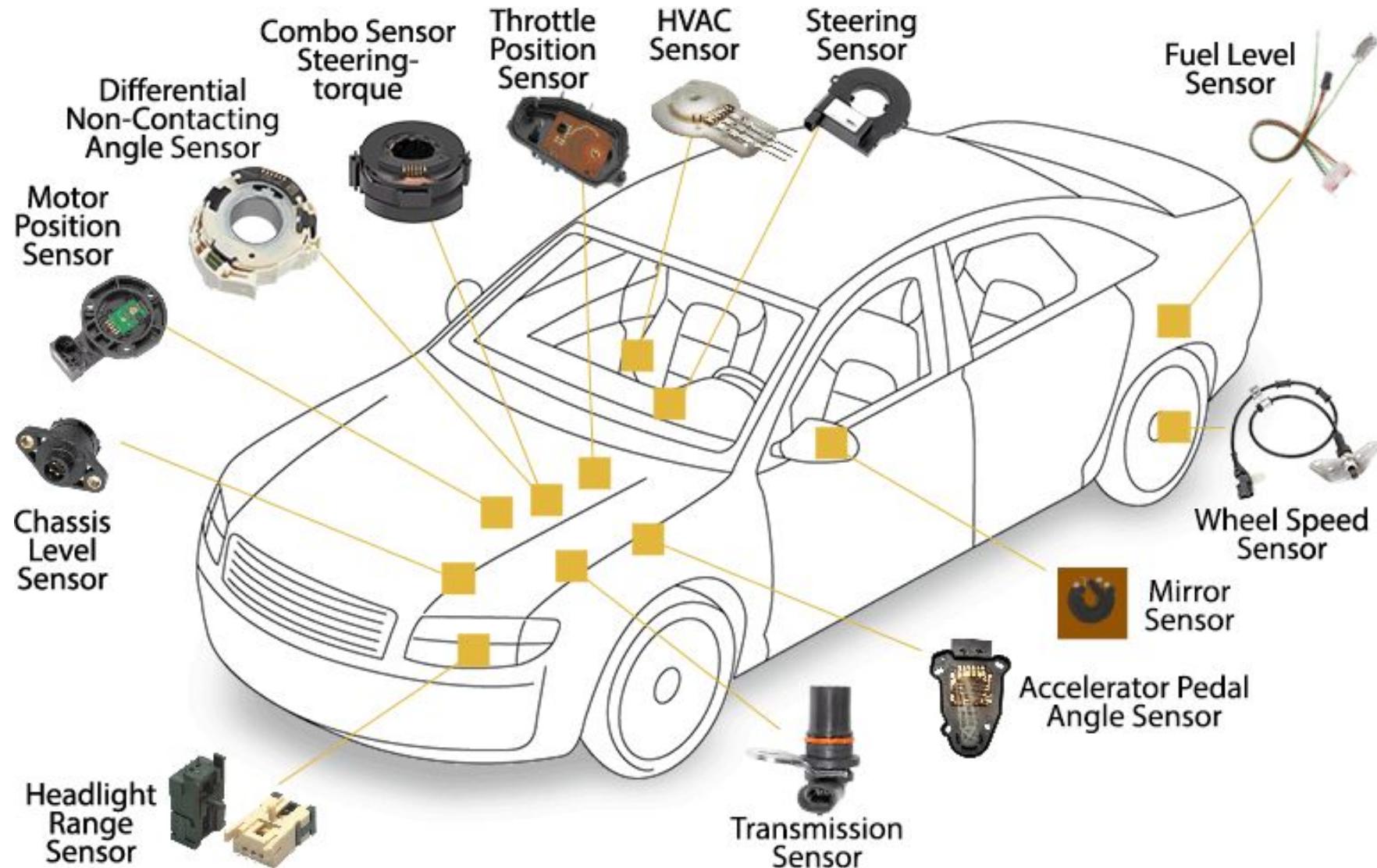
A Single Board Computer is a computer built on a single circuit board.

- Run only with operating systems.
- Can run more than one application at the same time.
- Need power to run all of the extra software.

Examples

- [Raspberry Pi](#)
- [Intel NUC](#)
- [NVIDIA Jetson](#)

The Sensors and Actuators



The Operating System (OS)

MICROCONTROLLER



Apache Nuttx



mbed OS

SINGLE BOARD COMPUTER



balenaOS



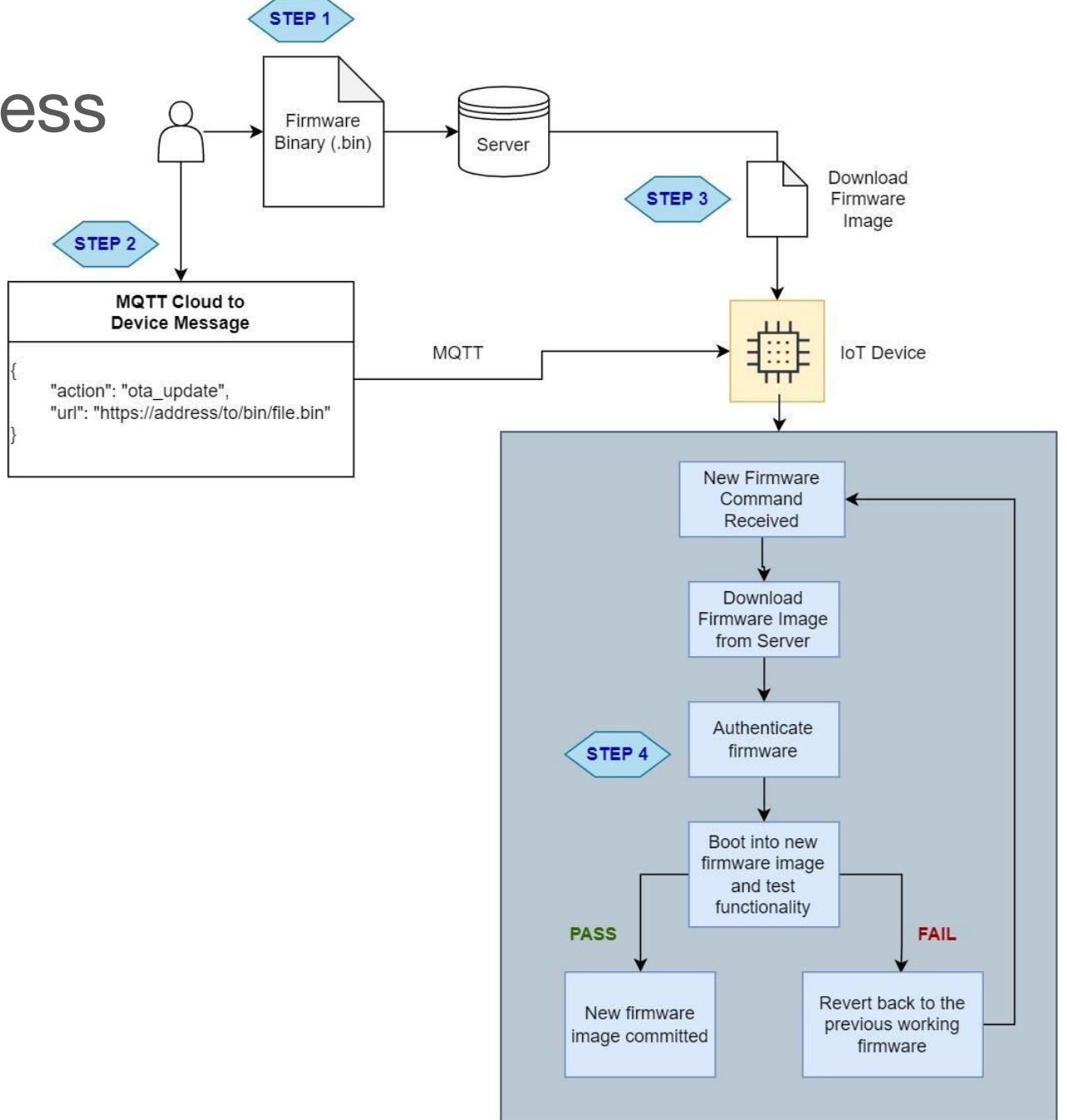
ubuntu



debian

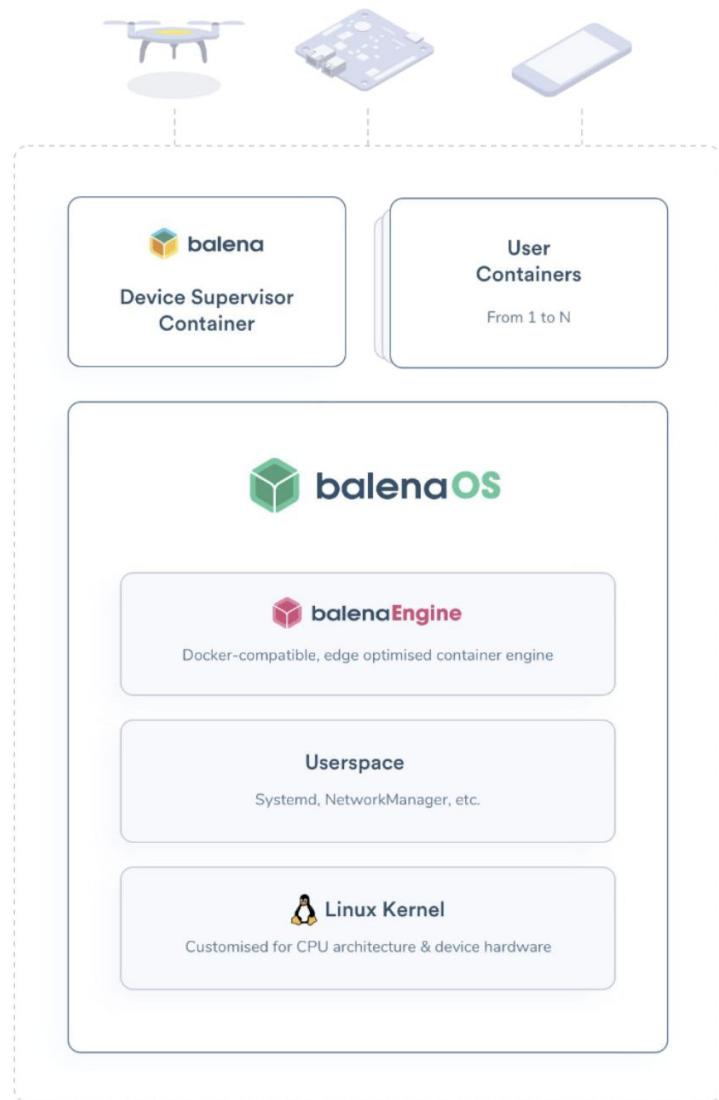


OTA Firmware update process



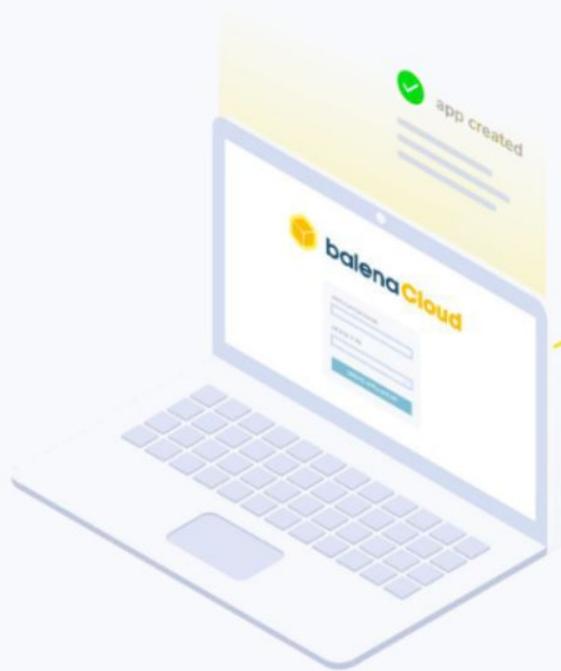
Example: What is balena?

Example: What is balena?



How it works

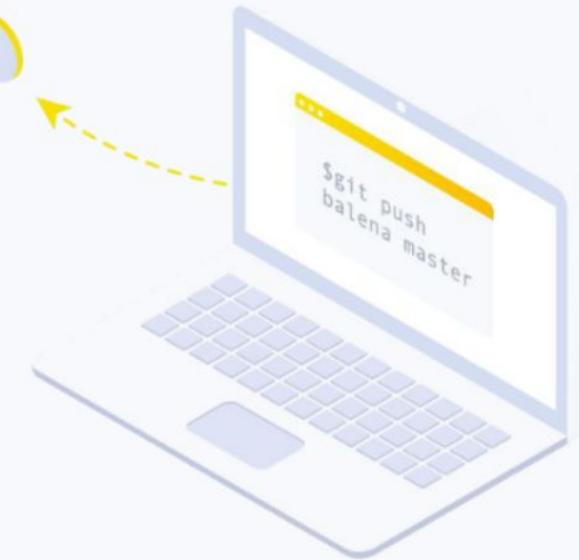
1 Setup your app



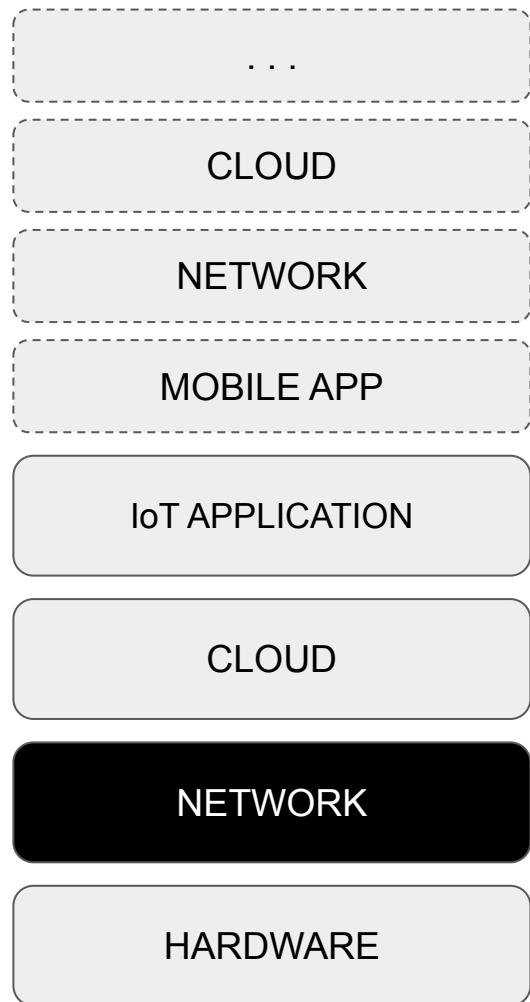
2 Flash your device



3 Push code



The IoT Stack (Zoom In)



Connectivity

- How are the devices connected to the Internet? (e.g. cellular communication, Bluetooth, WiFi, LoRa, Ethernet?)
- When devices are going to send data? (e.g. real-time, once a day, when an event happens?)
- Which kind of data is collected? (e.g. text, images, video?)
- Do they need bidirectional communication? or pulling once a day is enough?
- Does the communication module support secure encryption? What are the constraints of the hardware used?
- What QoS (Quality of Service) do you need on your communications? (e.g. is it ok to lose some messages or every message is critical)

Connetivity



NETWORKS



PROTOCOLS

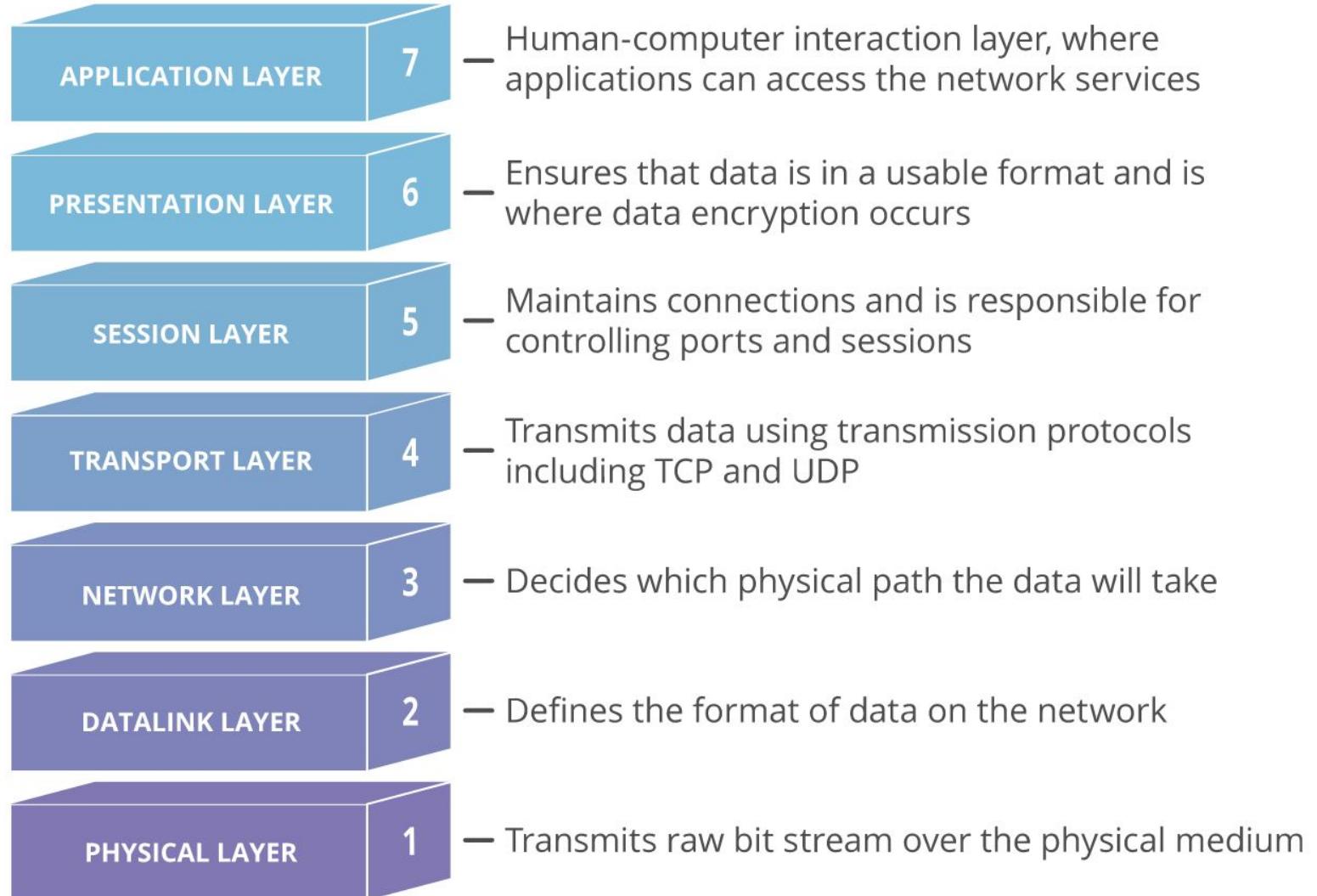


SERIALIZATION

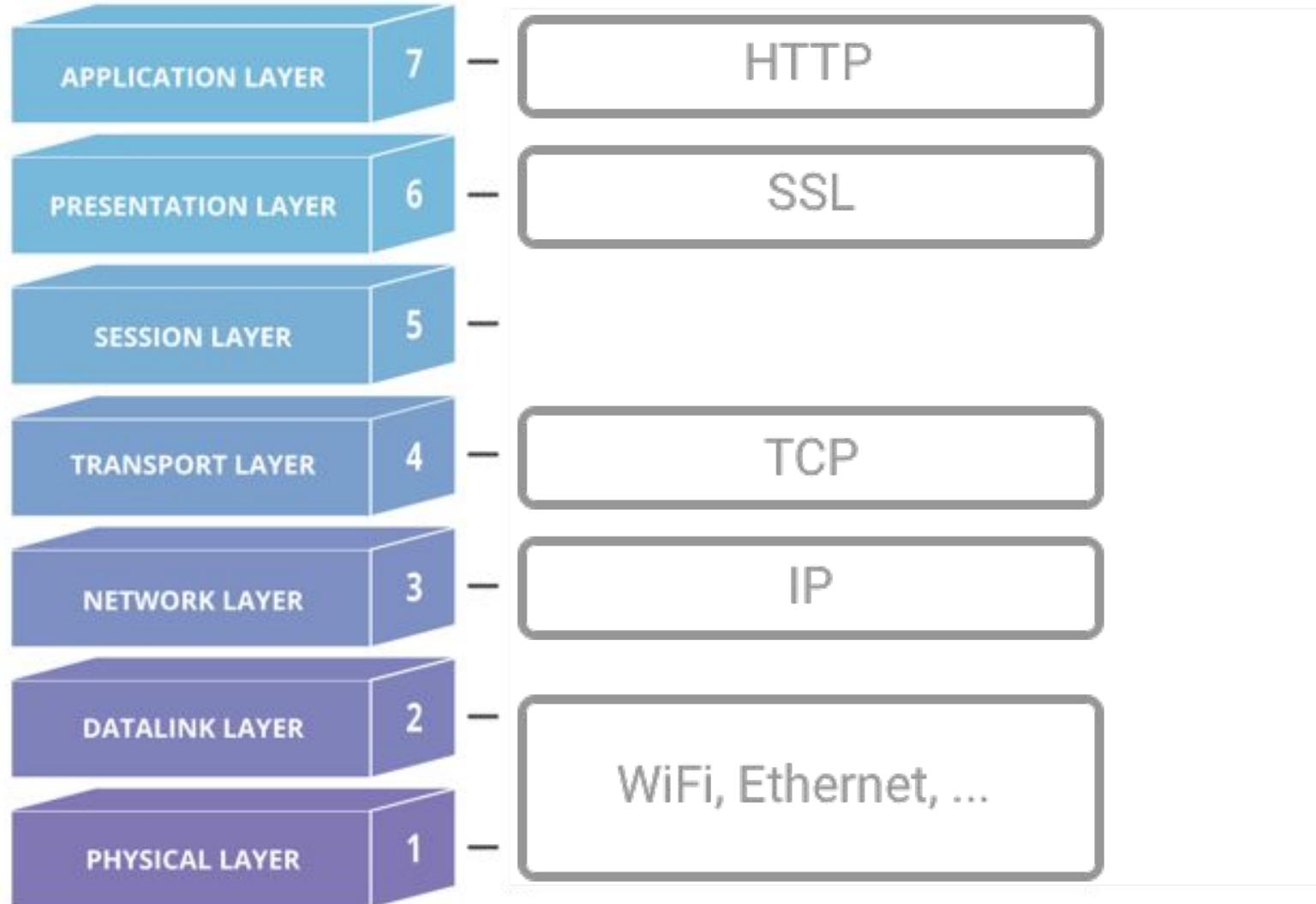


What is the best protocol to send data?

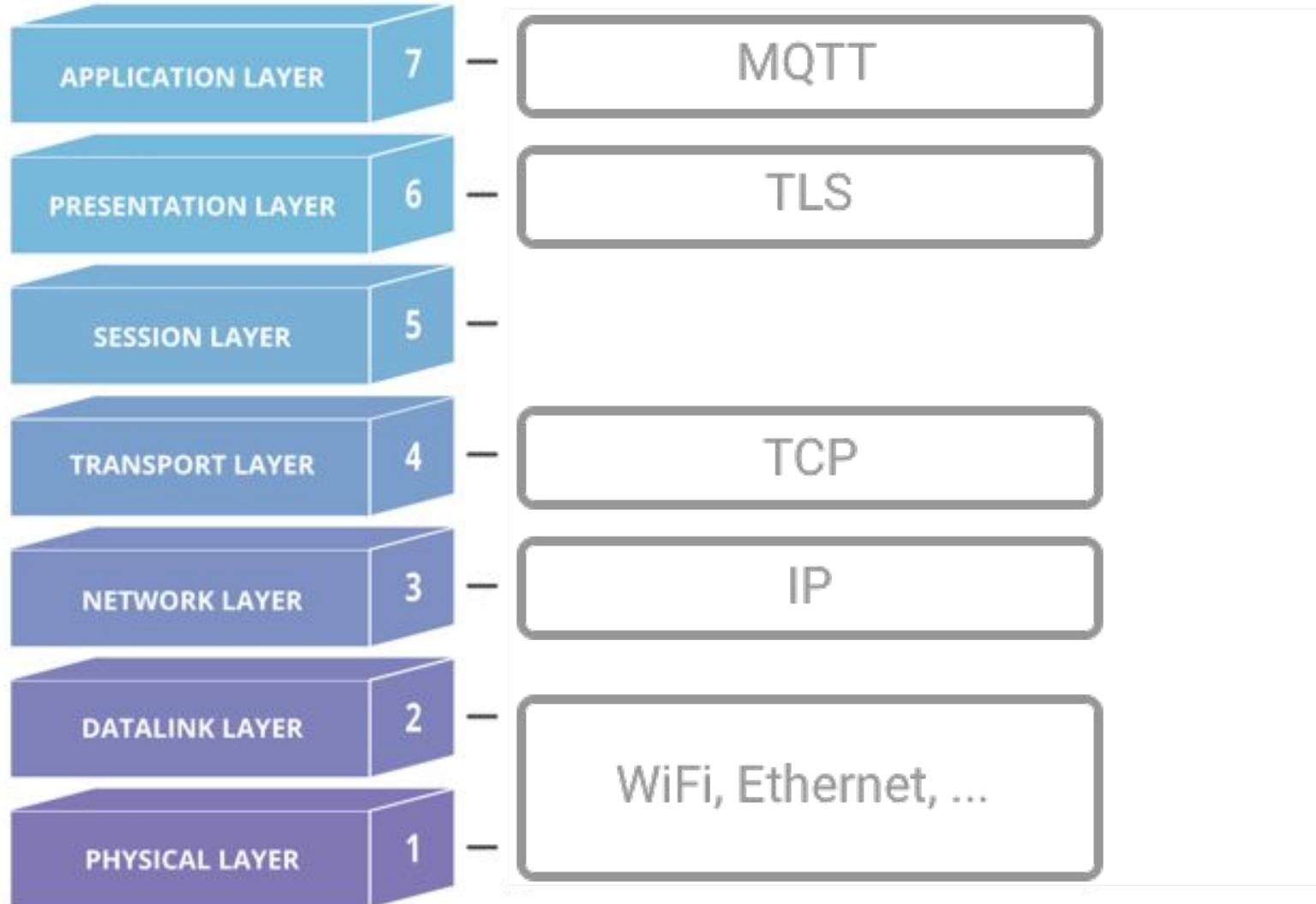
The OSI model



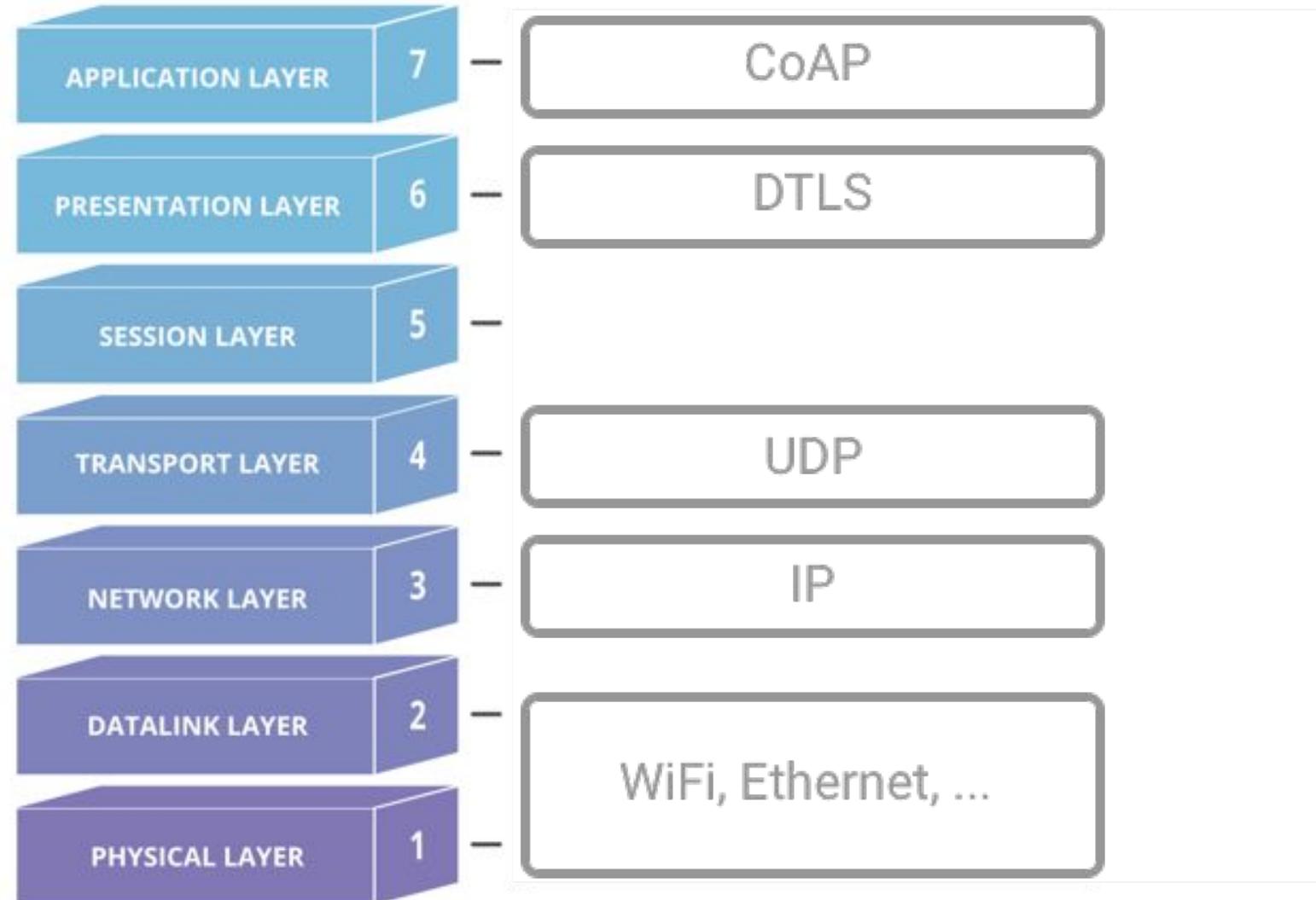
HTTP



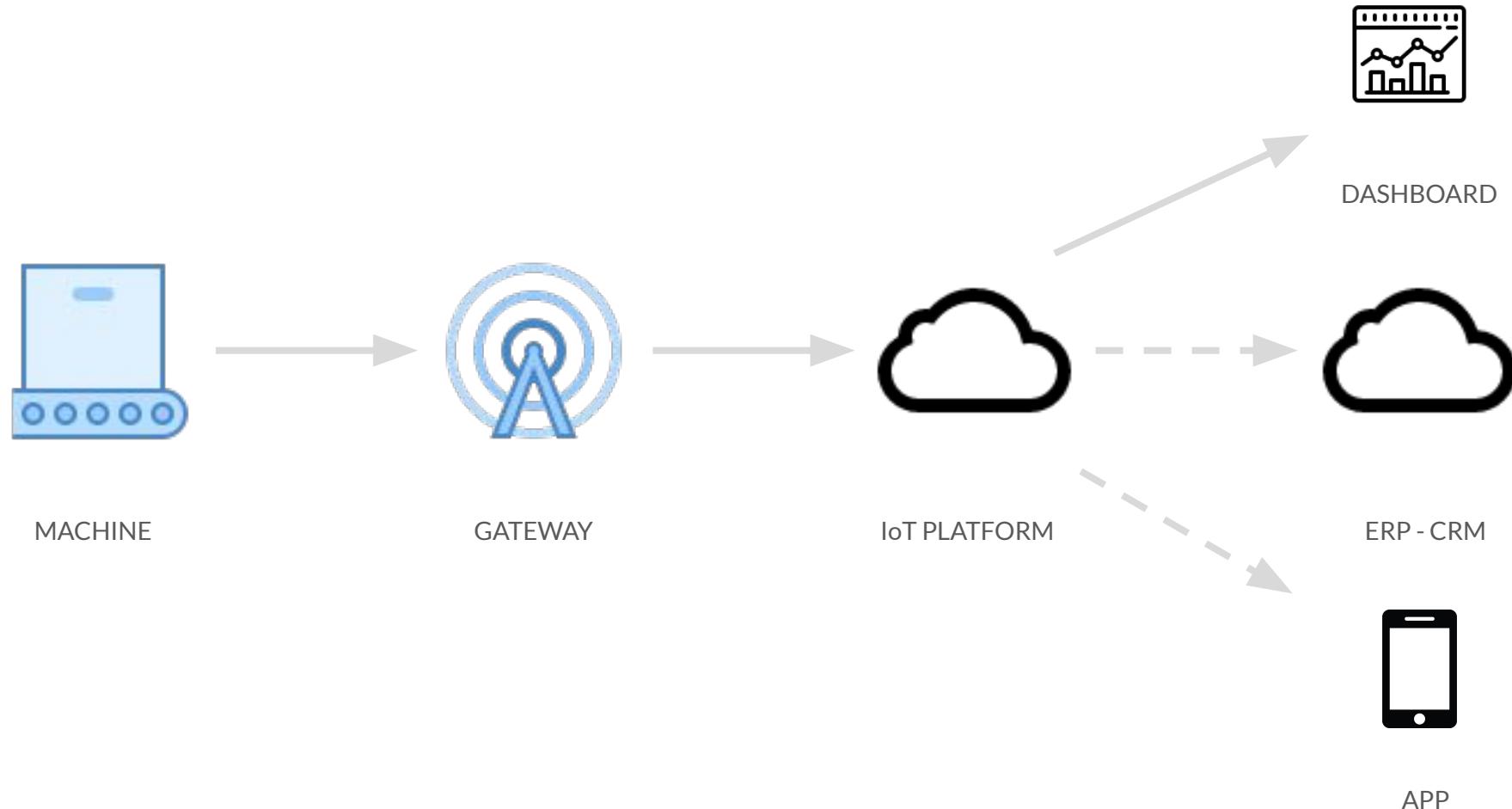
MQTT



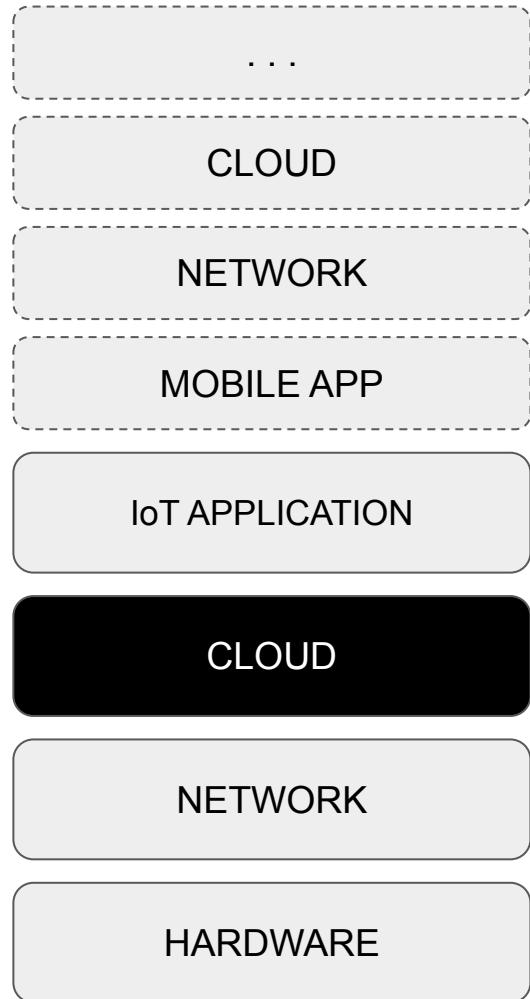
CoAP



Connectivity via Gateways



The IoT Stack (Zoom In)



The Cloud

The cloud is usually the backbone of your IoT solution.

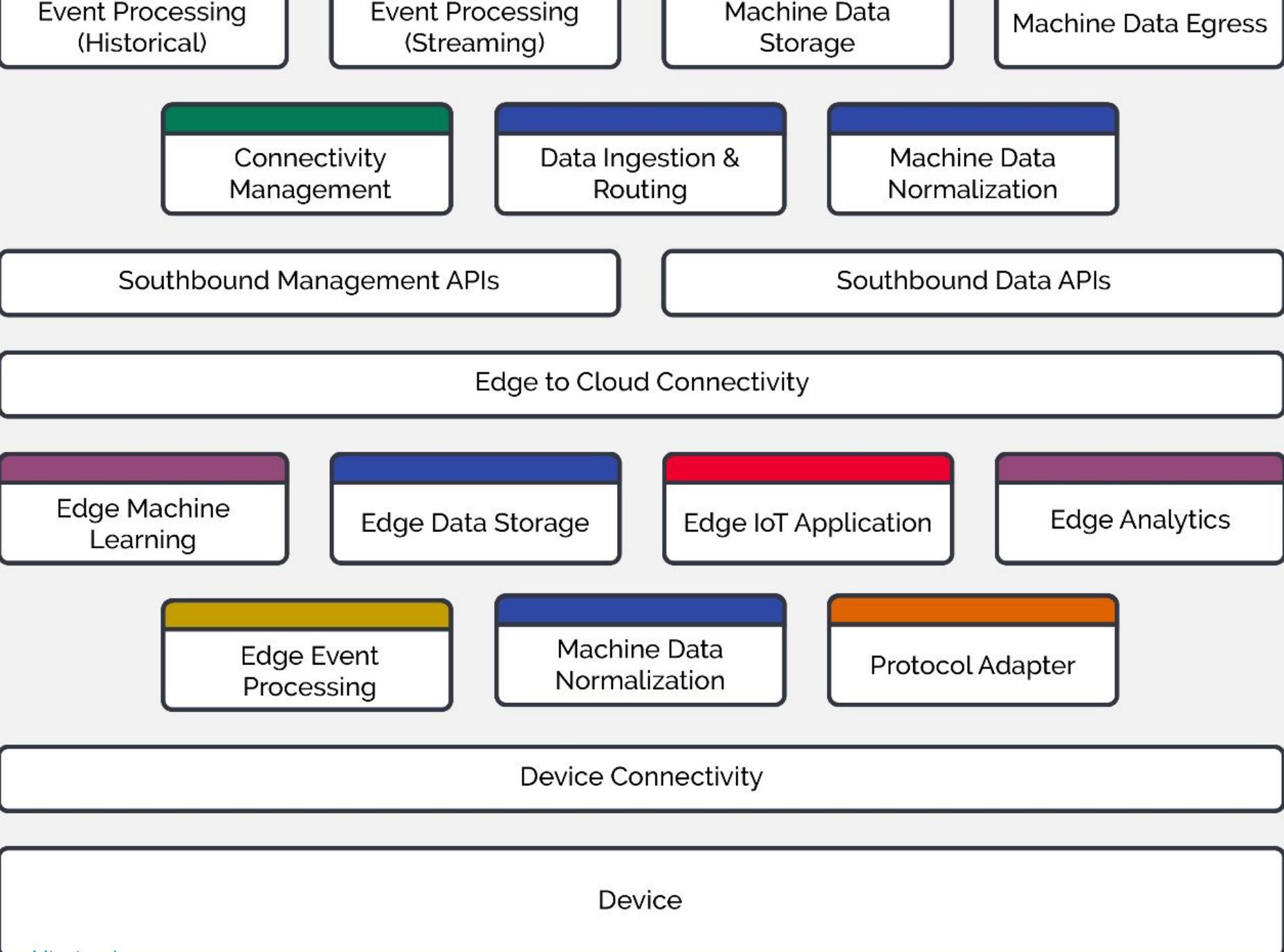
The Cloud

The cloud is usually the backbone of your IoT solution.

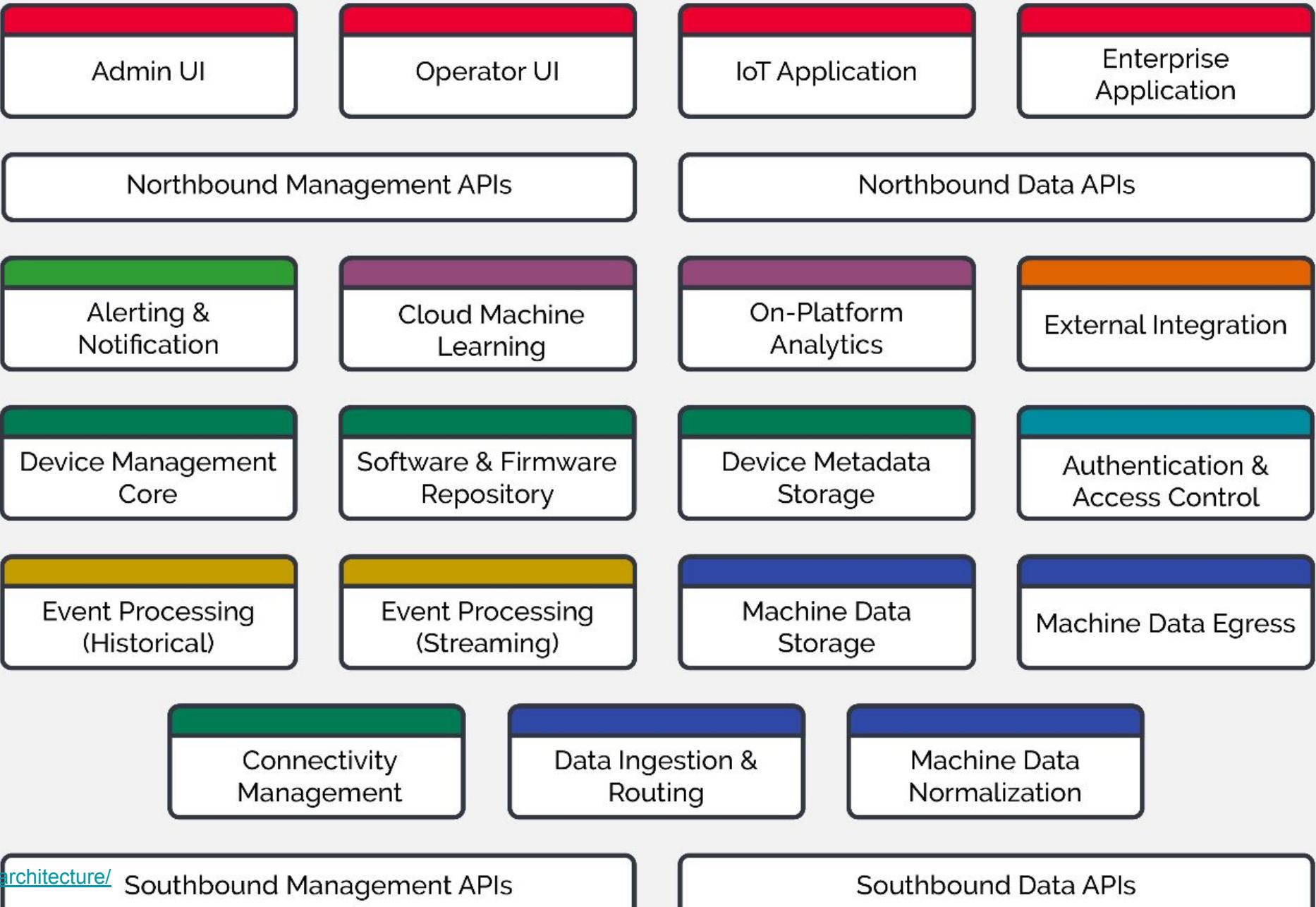
An IoT cloud platform have to support some critical areas:

- Analytics and monitoring
- Devices
- Connectivity
- Data
- Users
- Apps
- APIs
- Cloud computing
- Scalability and flexibility
- Enable a business model

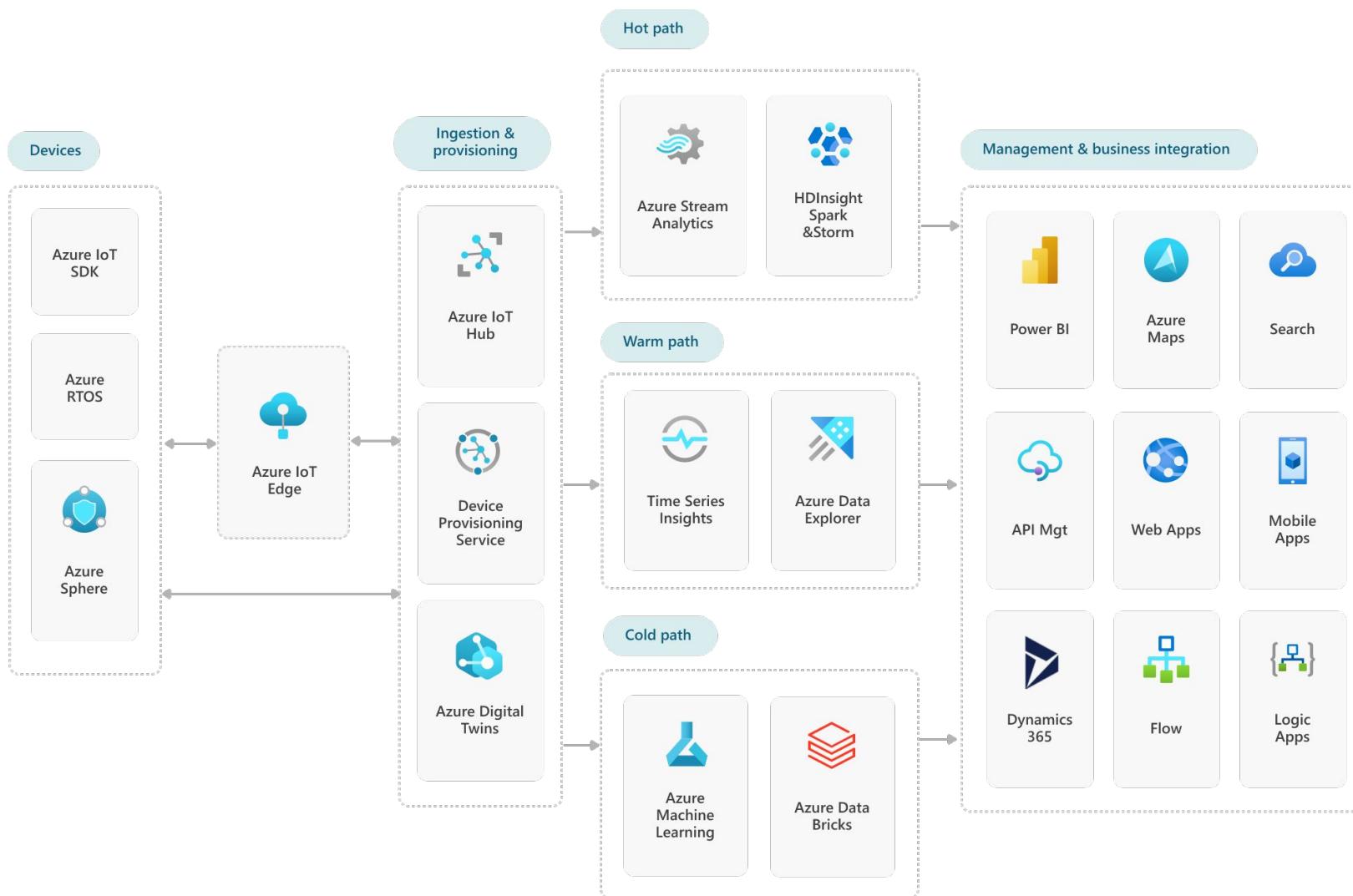
DEVICE



CLOUD

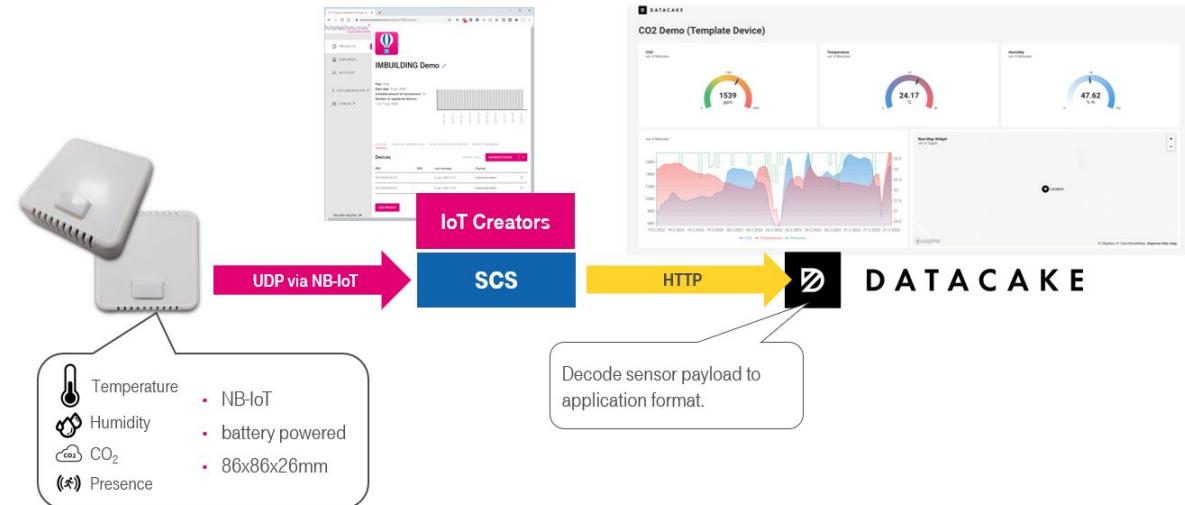


Example: The IoT Stack by Microsoft Azure

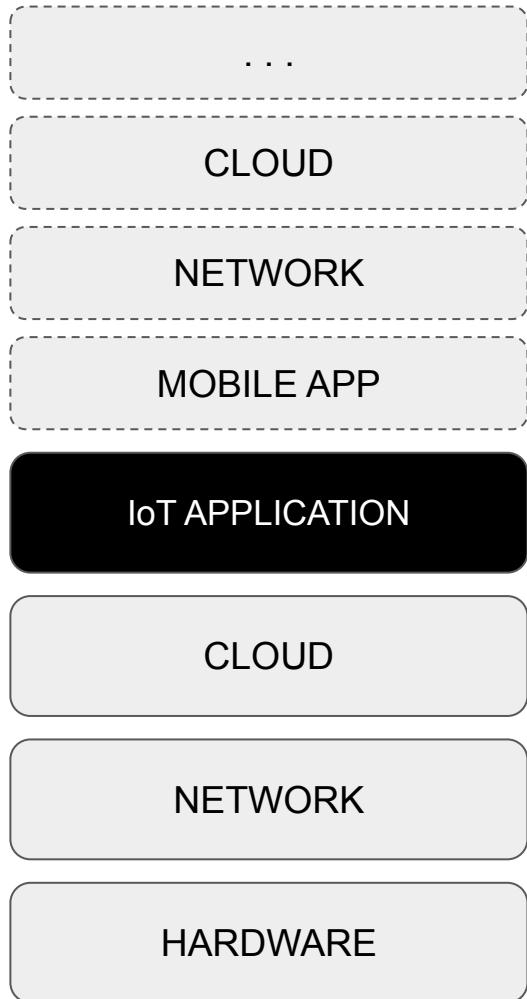


Example: Datacake

The screenshot shows the Datacake web interface for a Particle Asset Tracker 1 device. The top navigation bar includes 'Datacake' and 'Simons Worksp...', with a dropdown menu for 'Test2'. The main title is 'Particle Asset Tracker 1'. Key details shown are Location (empty), Serial Number (E00FCE68030389FA), Last update (Tue Dec 29 2020 19:08:56 GMT+0100), and Product Slug (particle-asset-tracker-1). Below this are tabs for Dashboard, History, Downlinks, Configuration, Debug, Rules, and Permissions. The Dashboard section displays four key metrics: Temperature (24.2 °C), Cellular Signal (45.4 %), Battery (54.7 %), and Battery loss per Day (-6.4 %). It also features a map showing the device's location in Germany with a path history from December 30, 2020, at 11:25 MEZ. Other sections include a 'New Map Widget' and a 'New Line Chart' showing battery and temperature data over time.



The IoT Stack (Zoom In)



The APIs

API (Application Programming Interface).

APIs are the key of a successful project.

If you want to integrate your IoT product with a 3rd party you need an API (and other protocols compatible).

Remember the southbound and northbound APIs from the architecture sketch.

The Applications

The Applications are based on the APIs.

Your resulting application depends on your use case and your business model.

What's your application?

The Applications

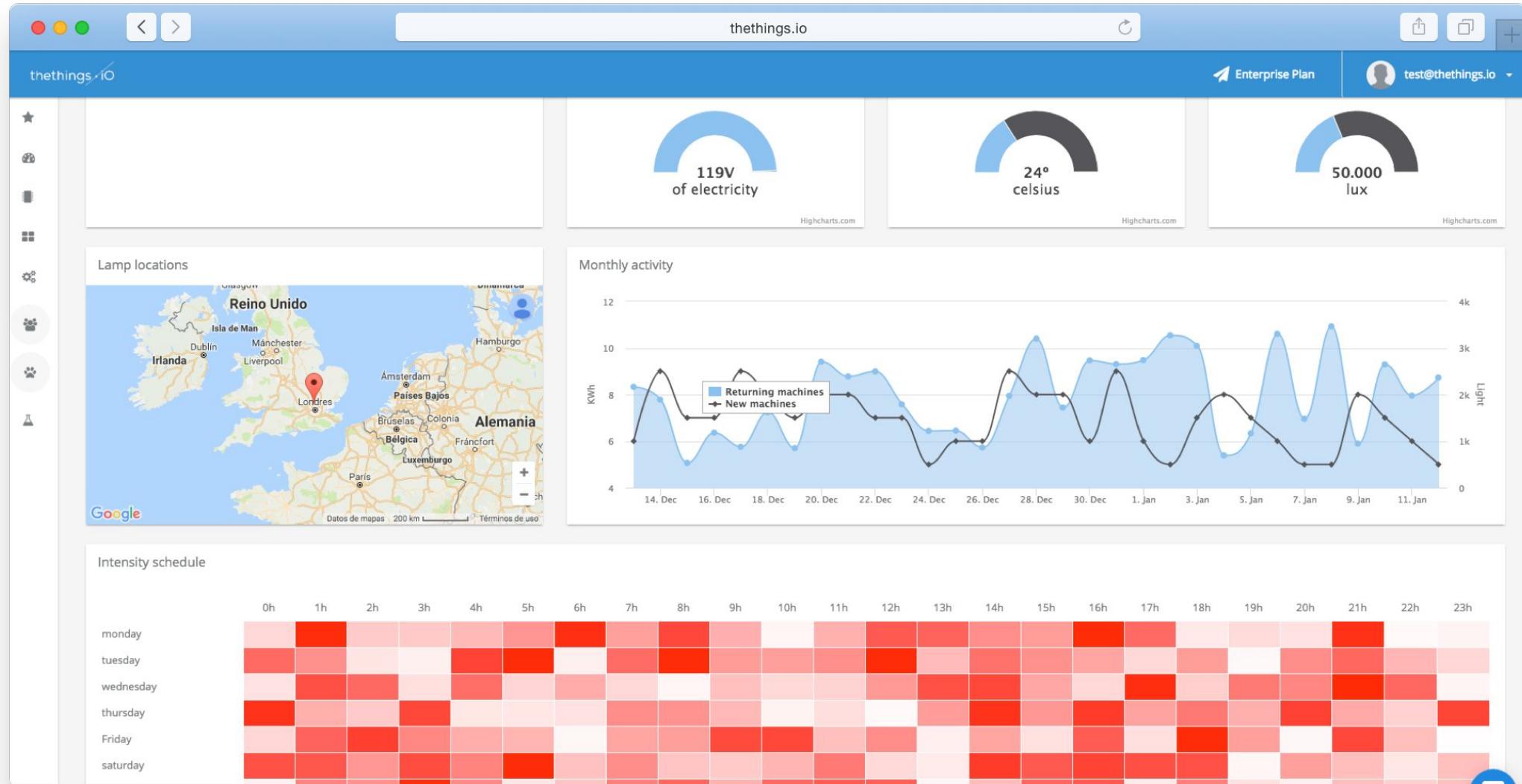
Is the mobile device the right tool for your IoT solution?

The Applications

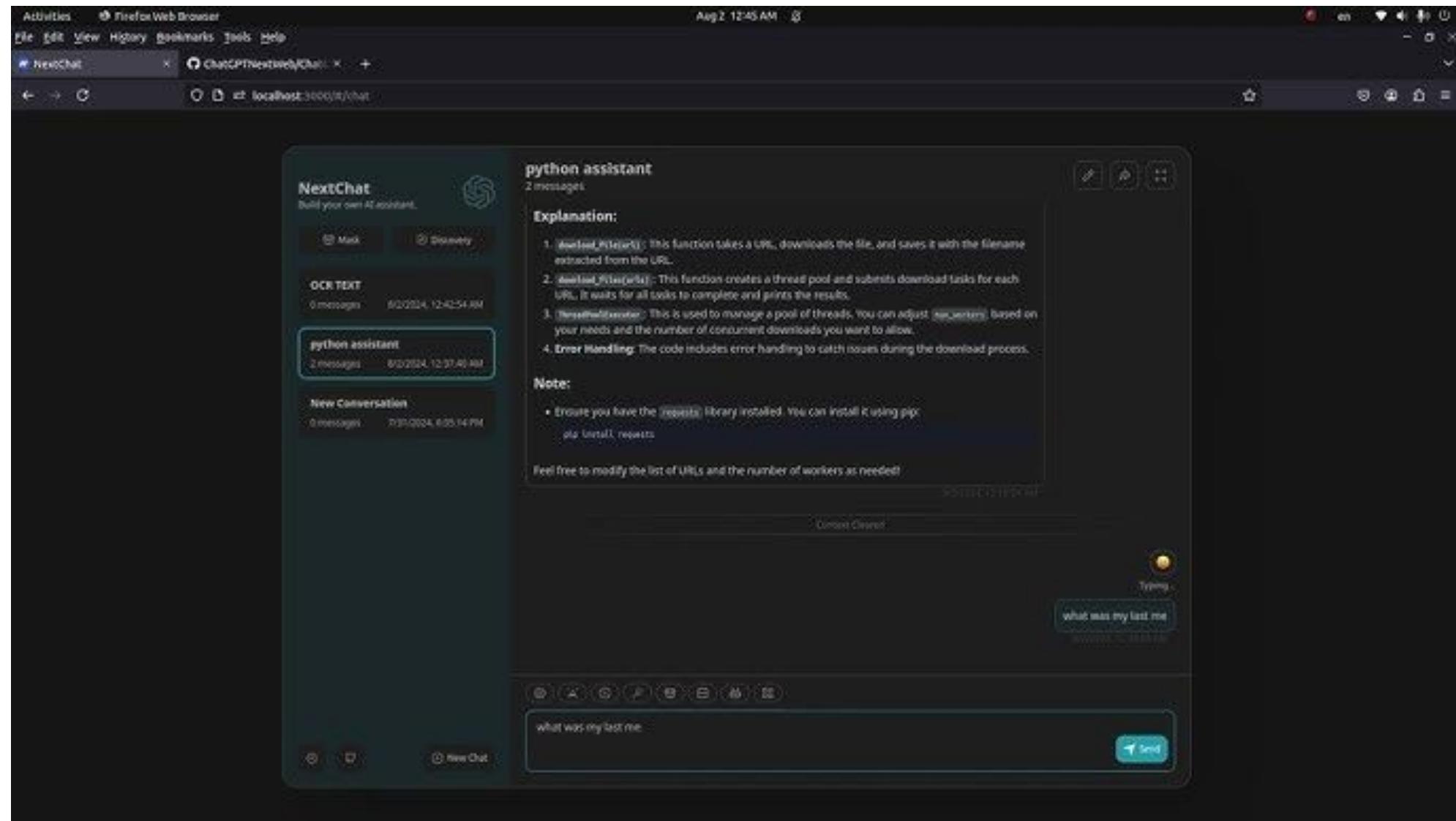
Is the virtual reality / metaverse an enabler for your IoT solution?



And dashboards?



And LLMs?



Systems needed for a company

Data from the devices must go to the usual interfaces from the company and not to a nice / beautiful dashboard.

Where?

- ERP
- MES
- Unified Namespace
- Digital Twin
- LLM
- Excel sheet
- ...

IoT Model Canvas

HARDWARE	CONNECTIVITY	DATA	APPS	ACTORS
PAYLOADS		CLOUD COMPUTING		
VALUE PROPOSITION		INTEGRATIONS		

IoT Model Canvas



by Marc Pous [@gy4nt](https://twitter.com/gy4nt)

HARDWARE	CONNECTIVITY	DATA	APPS	ACTORS		
Cortex A8 microprocessor Battery Interactive display IR sensor	Zigbee WiFi	Temperature Humidity Presence Temperature of the battery Devices around Settings	Nest APP API integrations	B2C Millennials and nerds People who want to save money and enjoy an autonomous heating system.		
PAYLOADS			CLOUD COMPUTING			
HTTPS			Processing information to sell the data to 3rd parties			
VALUE PROPOSITION		INTEGRATIONS				
Easy to install and programmable thermostat that sets the best settings to achieve maximum energy savings.		Google Products REST API				

IoT Model Canvas: Nest Thermostat

HARDWARE	CONNECTIVITY	DATA	APPS	ACTORS
PAYLOADS		CLOUD COMPUTING		
VALUE PROPOSITION		INTEGRATIONS		

IoT Model Canvas



by Marc Pous [@gy4nt](https://twitter.com/gy4nt)

Example: Automation stack on the Industry 4.0

CLOUD

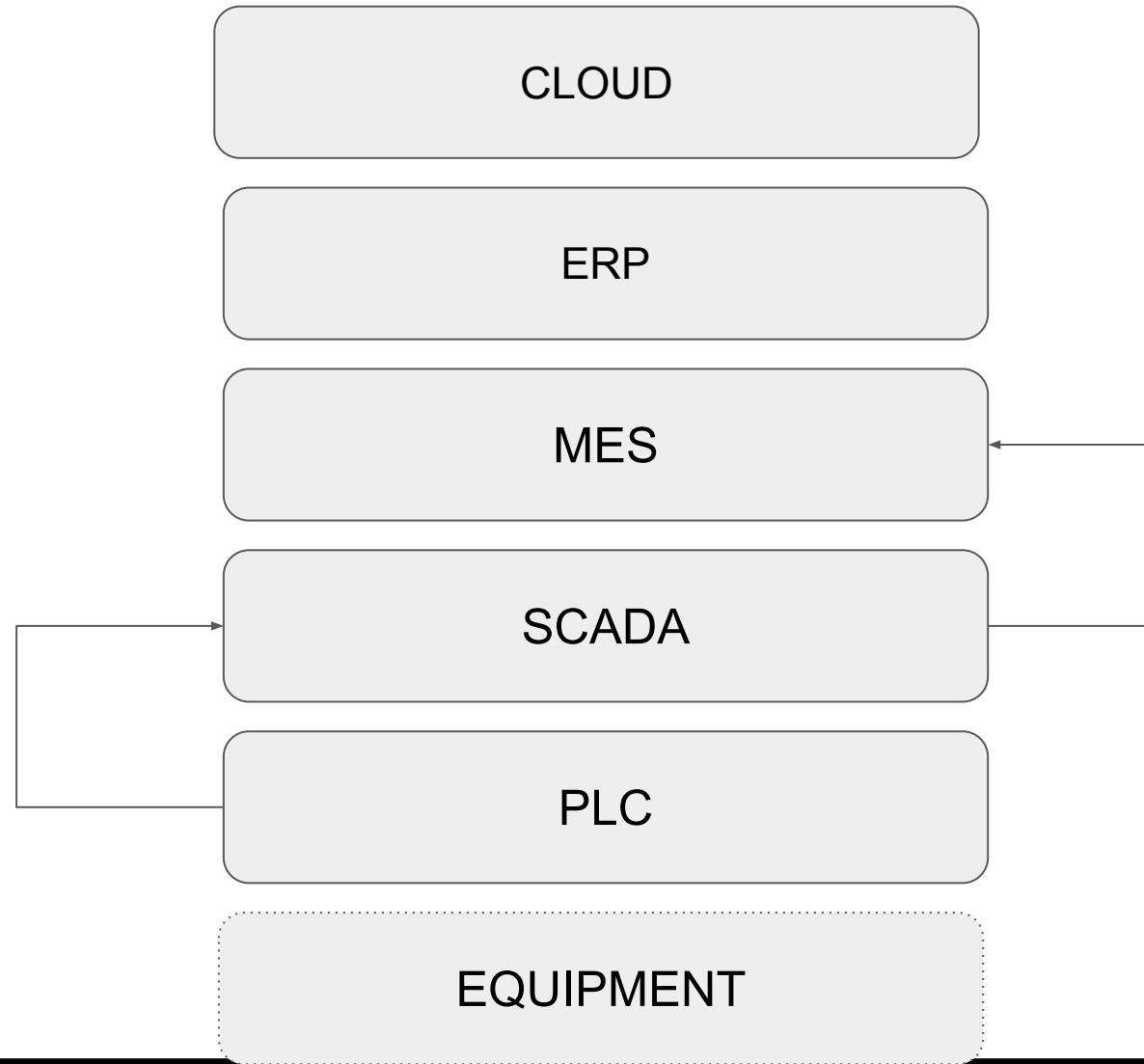
ERP

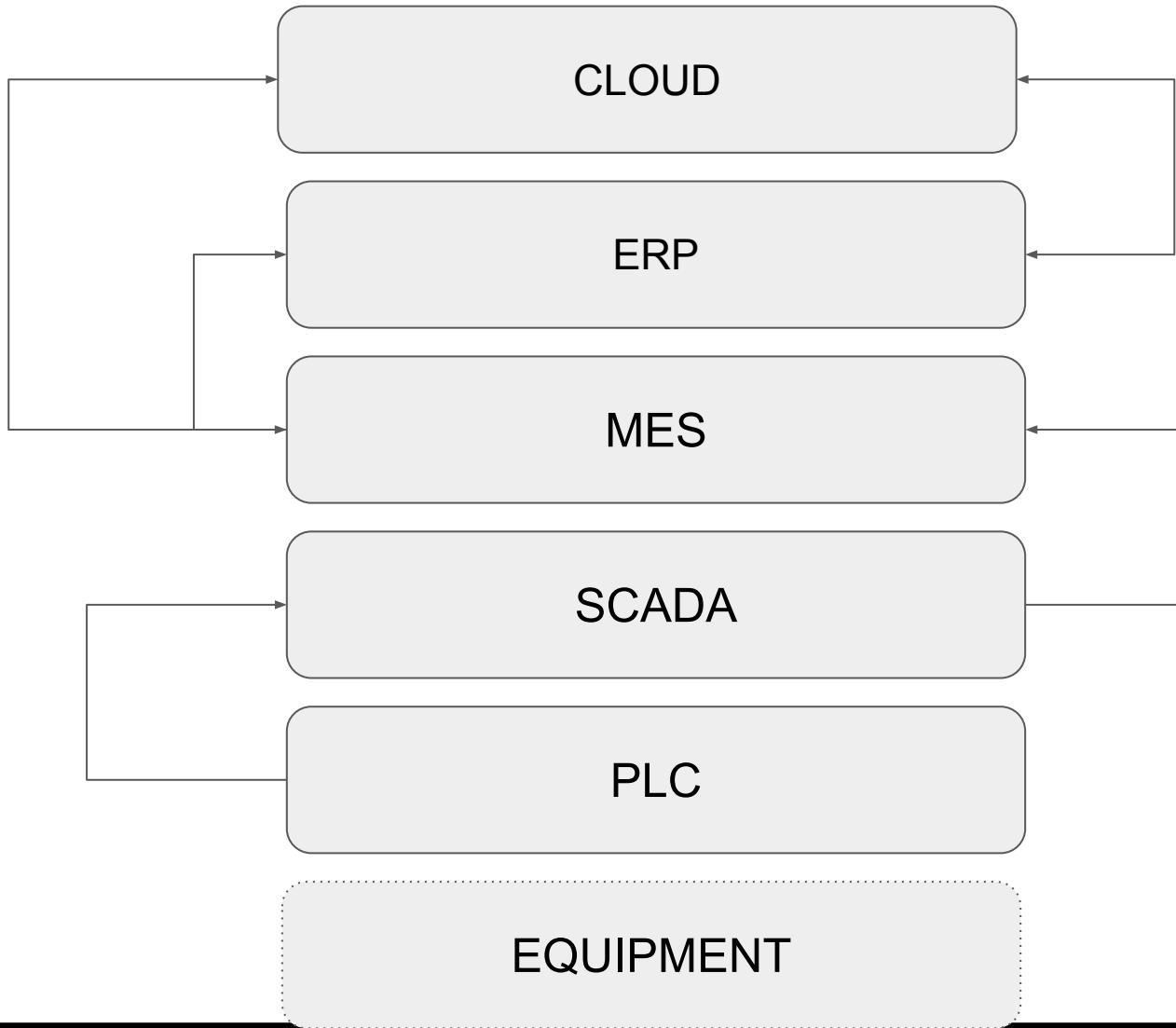
MES

SCADA

PLC

EQUIPMENT





CLOUD

ERP

MES

SCADA

PLC

PLC₂

How is this being
integrated with the SCADA?

EQUIPMENT

CLOUD

ERP

MES

SCADA

PLC

PLC₂

EQUIPMENT

How is this being
integrated with the SCADA?



OEM



Industry 4.0 goal is to break all of these silos and save money!

How is this being integrated with the SCADA?



The Unified Namespace (UNS)

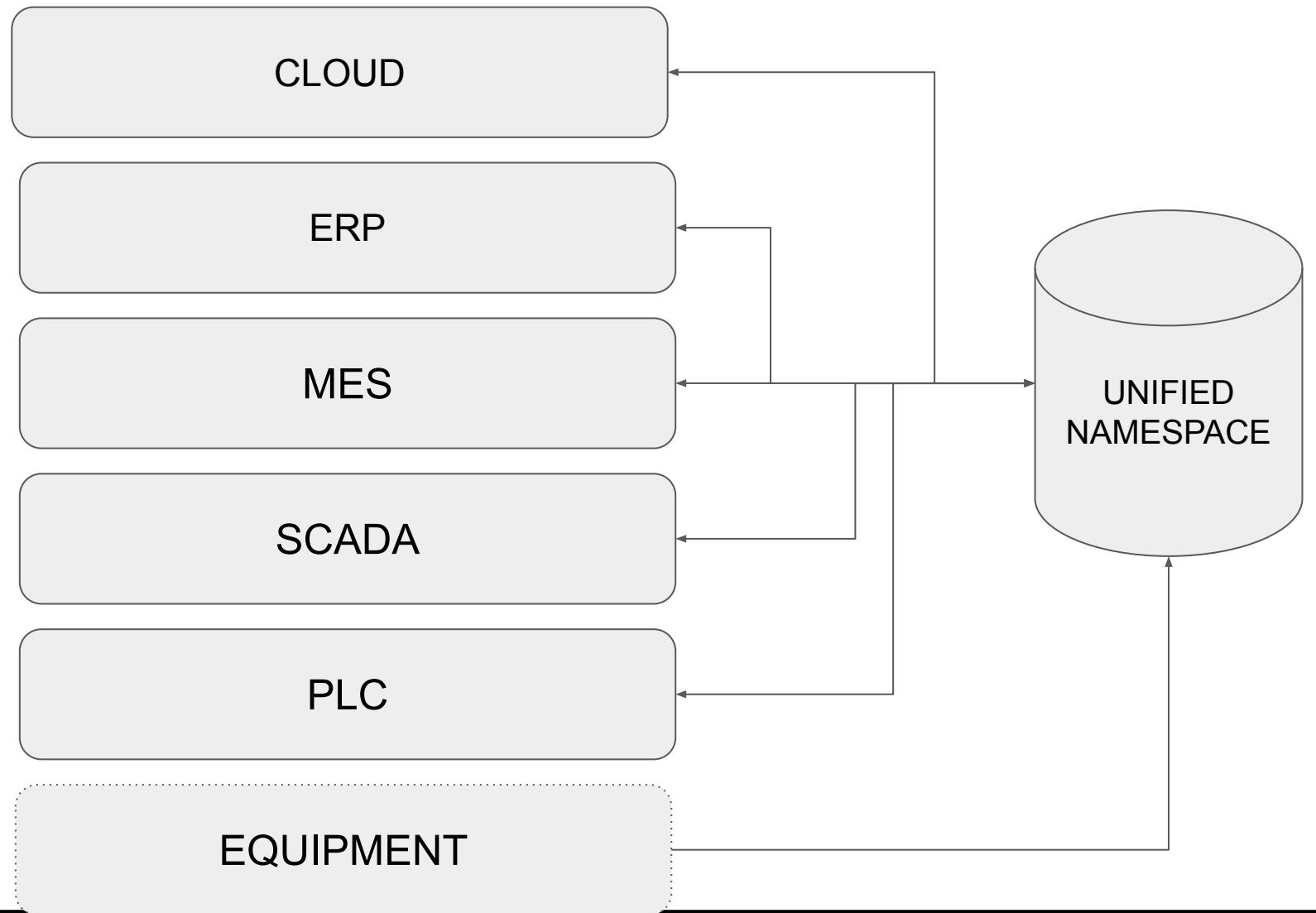
To scale any industrial IoT implementation, the key part is a **unified namespace**.

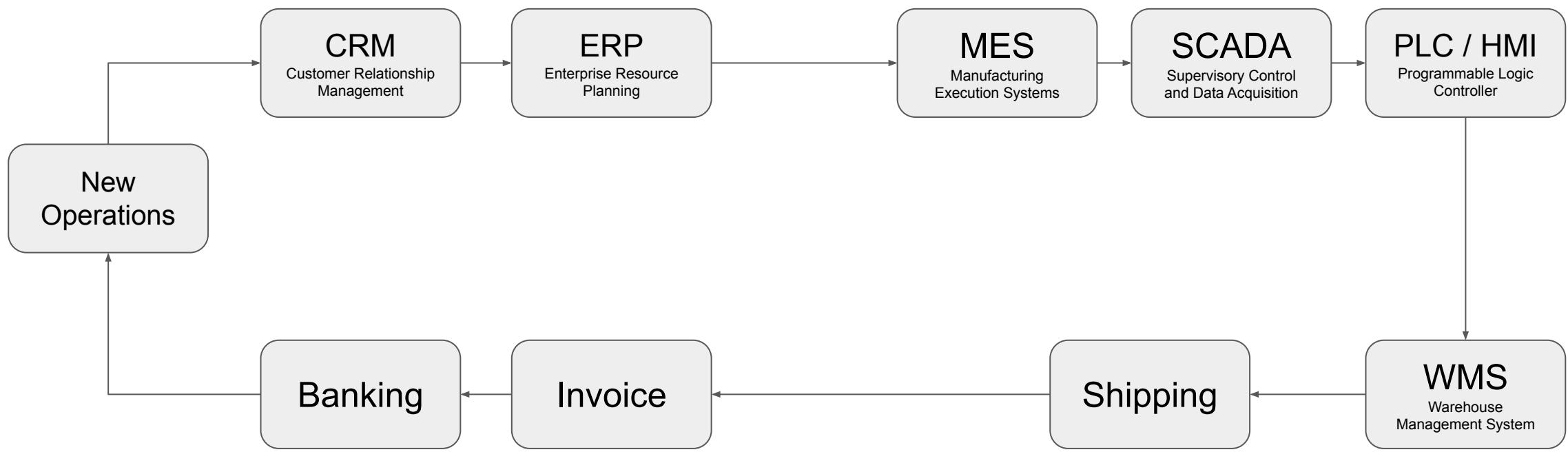
A unified namespace is an abstract layer that acts as a centralized repository of data, information, and context where any application or device can consume or publish data needed for a specific action.

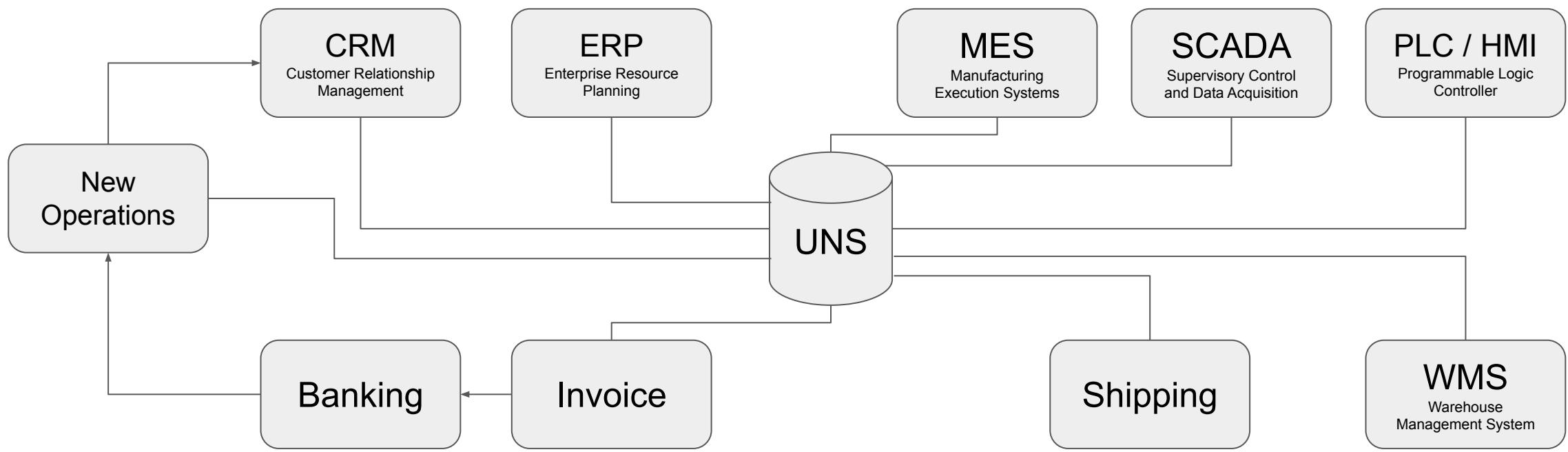
Using a unified namespace everything in the factory acts as a node of the namespace.

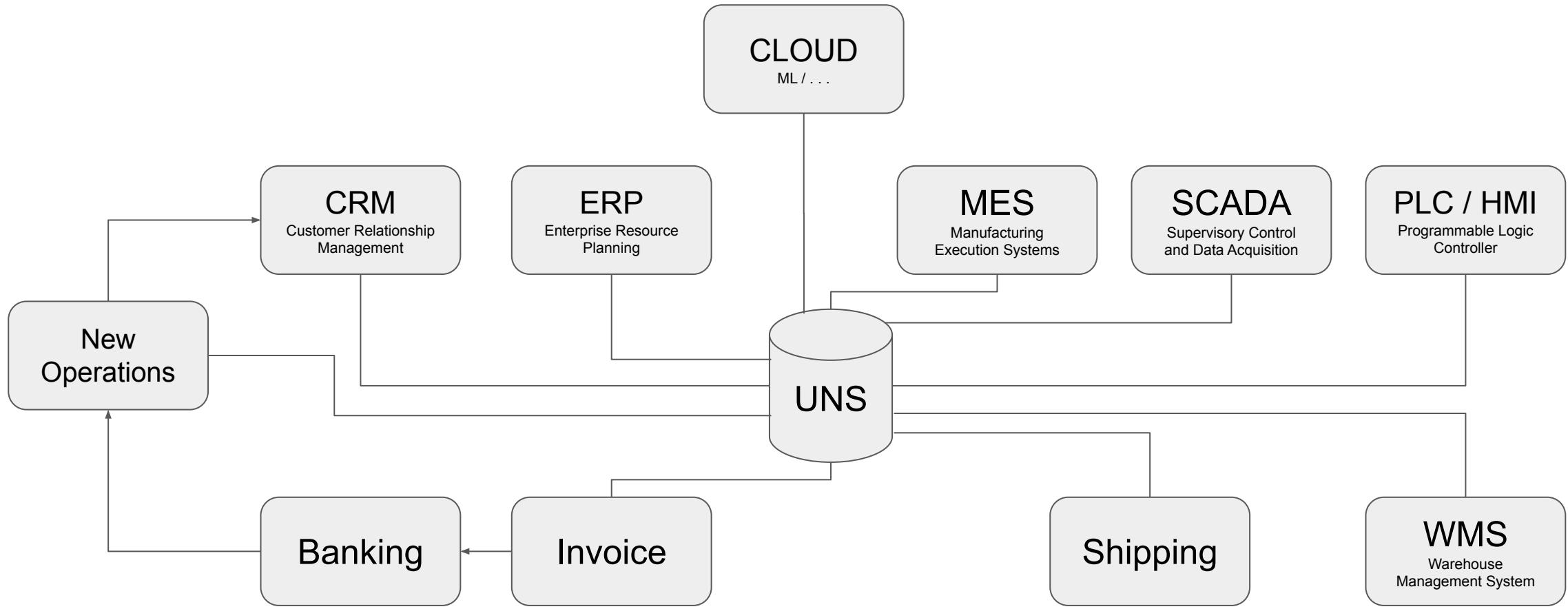
Without a centralized data repository (data warehouse), it could take *months* to deploy a new analytics application across the entire enterprise versus *hours* with a unified namespace.

The Unified Namespace

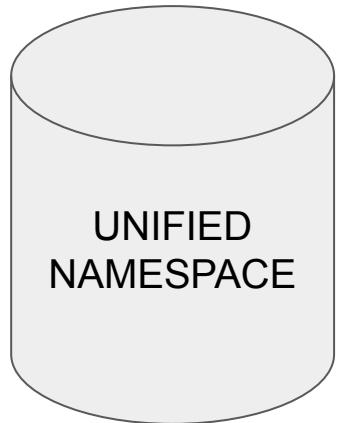








What is a UNS?



On the Industry 4.0, the Unified Namespace is the single source of truth of your enterprise / factory.

Its goal is to brings data from all the proprietary protocols from the factory, in a single way, to a Data Warehouse that manages the IIoT Architecture.

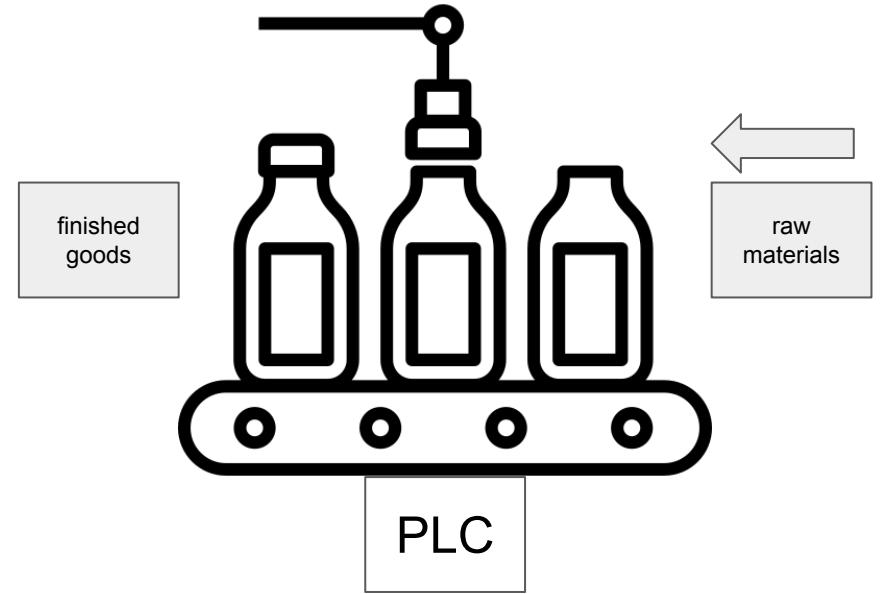
The main technology used in the UNS concept is MQTT.

UNS: The MQTT topics following the ISA-95 standard

- Enterprise
 - Site 1
 - Area 1
 - Line 1
 - Machine 1
 - Machine 2
 - Machine 3
 - Line 2
 - Area 2
 - Area 3
 - Site 2
 - Site 3
 - Site 4
 - Site 5

UNS: The MQTT topics following the ISA-95 standard

- Enterprise
 - Site 1
 - Area 1
 - Line 1
 - Machine 1
 - Machine 2
 - Machine 3
 - Line 2
 - Area 2
 - Area 3
 - Site 2
 - Site 3
 - Site 4
 - Site 5





▼ 127.0.0.1

► spBv1.0 (3 topics, 3 messages)

▼ Digital Transformation

Phase = 1

▼ Enterprise

▼ Site 1

▼ Area

▼ Line 1

▼ MES

▼ KPIs

Availability = 0.62



Quality = 0.57

Performance = 0.75

OEE = 0.11

TEEP = 0.01

MTTR = 1381

MTBF = 1418

▼ Edge

Infeed = 48.14

Outfeed = 62.91

Waste = 14.77

State = 1

☰ MQTT Explorer

▼ 127.0.0.1

► spBv1.0 (3 topics, 3 messages)

▼ Digital Transformation

Phase = 1

▼ Enterprise

▼ Site 1

▼ Area

▼ Line 1

▼ MES

▼ KPIs

Availability = 0.62

Quality = 0.57

Performance = 0.75

OEE = 0.11

TEEP = 0.01

MTTR = 1381

MTBF = 1418

▼ Edge

Infeed = 48.14

Outfeed = 62.91

Waste = 14.77

State = 1

☰ MQTT Explorer 🔍 Search...

▼ 127.0.0.1

▶ spBv1.0 (3 topics, 3 messages)

▼ Digital Transformation

 Phase = 2

▼ Enterprise

 ▼ Site 1

 ▼ Area

 ▼ Line 1

 ▶ MES (8 topics, 9 messages)

 ▶ Edge (4 topics, 4 messages)

 ▼ ERP

 ▼ ProductionOrder

 OrderNumber = 8826

 OrderStatus = "Completed"

 ScheduledStartTime = "2023-12-02 19:05:40"

 ScheduledEndTime = "2023-12-12 19:05:40"

 ActualStartTime = "2023-12-05 19:05:40"

 ActualEndTime = "2023-12-06 19:05:40"

 OrderedQuantity = 986

 ProducedQuantity = 436

 RemainingQuantity = 160

 ▼ Inventory

 ItemNumber = 53658

 BOM = "data<input type='text' value='dataset' style='width: 200px;'>"

 ItemDescription = "Item Description 53658"

 AvailableQuantity = 440

 ReservedQuantity = 314

 OrderedQuantity = 986

MQTT Explorer

Search...

▼ 127.0.0.1
► spBv1.0 (3 topics, 3 messages)

▼ Digital Transformation

Phase = 3

▼ Enterprise

▼ Site 1

▼ Area

▼ Line 1

► MES (19 topics, 20 messages)

▼ Edge

Infeed = 48.14

Outfeed = 62.91

Waste = 14.77

State = 1

▼ Process

SpindleSpeed = 1621

FeedRate = 1.2752394805831337

ToolWear = 0.5070888655308258

CoolantTemperature = 29.181826408532817

Vibration = 1.0772042172363667

PowerConsumption = 46.99291891174136

ToolChangeCount = 4

MaterialTemperature = 66.96252967921029

PartDimensions = "2.0220156547621952x3.9654574643124456"

SurfaceFinish = "Rough"

▼ ERP

► ProductionOrder (9 topics, 18 messages)

► Inventory (7 topics, 14 messages)

MQTT Explorer

Search...

▼ 127.0.0.1
► spBv1.0 (3 topics, 3 messages)

▼ Digital Transformation

Phase = 3

▼ Enterprise

▼ Site 1

▼ Area

▼ Line 1

► MES (8 topics, 9 messages) = 2

▼ Quality

OrderNumber = 1891

ItemNumber = 46718

InspectionResult = "Pass"

RejectionReason = "N/A"

RejectionQuantity = 0

AcceptedQuantity = 74

▼ Maintenance

MachineID = "Machine-68"

MaintenanceStatus = "Overdue"

LastMaintenanceDate = "2023-11-24 19:07:21"

NextMaintenanceDate = "2023-12-21 19:07:21"

MaintenanceHistory = "Last serviced 2023-11-24 19:07:21"

▼ Edge

Infeed = 48.14

Outfeed = 62.91

Waste = 14.77

State = 1



▼ 127.0.0.1

- ## ► spBv1.0 (3 topics, 3 messages)

▼ Digital Transformation

Phase = 4

▼ Enterprise

▼ Site 1

▼ Area

▼ Line 1

- ▶ KPIs (8 topics, 9 messages) = 2
 - ▶ Quality (6 topics, 6 messages)
 - ▶ Maintenance (5 topics, 5 messages)

▼ Edge

Infeed = 48.14

Outfeed = 62.91

Waste = 14.77

State = 1

- ## ► Process (10 topics, 10 messages)

▼ ERP

- ▶ ProductionOrder (9 topics, 18 messages)
 - ▶ Inventory (7 topics, 14 messages)

MQTT Explorer

Search...

- ▼ 127.0.0.1
 - spBv1.0 (3 topics, 3 messages)
 - ▼ Digital Transformation
 - Phase = 5
 - ▼ Enterprise
 - ▼ Site 1
 - ▼ Area
 - ▼ Line 1
 - ▼ MES
 - ▶ KPIs (8 topics, 9 messages) = 2
 - ▶ Quality (6 topics, 12 messages)
 - ▶ Maintenance (5 topics, 10 messages)
 - ▼ Edge
 - Infeed = 48.14
 - Outfeed = 62.91
 - Waste = 14.77
 - State = 1
 - ▶ Process (10 topics, 20 messages)
 - ▼ ERP
 - ▶ ProductionOrder (9 topics, 18 messages)
 - ▶ Inventory (7 topics, 14 messages)
 - 55001 = {"AssetLifecycle": {"Status": "Decommissioned"}
S88 = {"BatchControl": {"EquipmentModule": {"BatchMi}}
 - Line 2 (49 topics, 49 messages)

MQTT Explorer

Search...

- ▼ 127.0.0.1
 - spBv1.0 (3 topics, 3 messages)
 - ▼ Digital Transformation
 - Phase = 6
 - ▼ Enterprise
 - ▼ Site 1
 - ▼ Area
 - ▼ Line 1
 - MES (19 topics, 31 messages)
 - Edge (14 topics, 24 messages)
 - ERP (16 topics, 32 messages)
 - 55001 = {"AssetLifecycle": {"Status": "Decommissioned"}
S88 = {"BatchControl": {"EquipmentModule": {"BatchMi}}
 - ▼ Line 2
 - MES (18 topics, 18 messages)
 - Edge (14 topics, 14 messages)
 - ERP (15 topics, 15 messages)
 - 55001 = {"AssetLifecycle": {"Status": "Decommissioned"}
S88 = {"BatchControl": {"EquipmentModule": {"BatchMi}}
 - ▼ Line 3
 - MES (18 topics, 18 messages)
 - Edge (14 topics, 14 messages)
 - ERP (15 topics, 15 messages)
 - 55001 = {"AssetLifecycle": {"Status": "Decommissioned"}
S88 = {"BatchControl": {"EquipmentModule": {"BatchMi}}}

EOF