Ensuring Reliable Networks TTTech

Fog Computing as Enabler for the Industrial Internet of Things / Industrie 4.0

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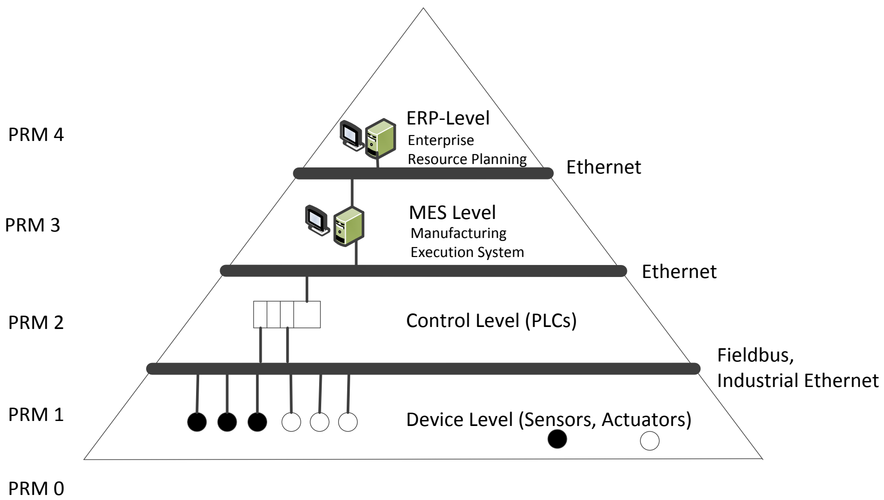
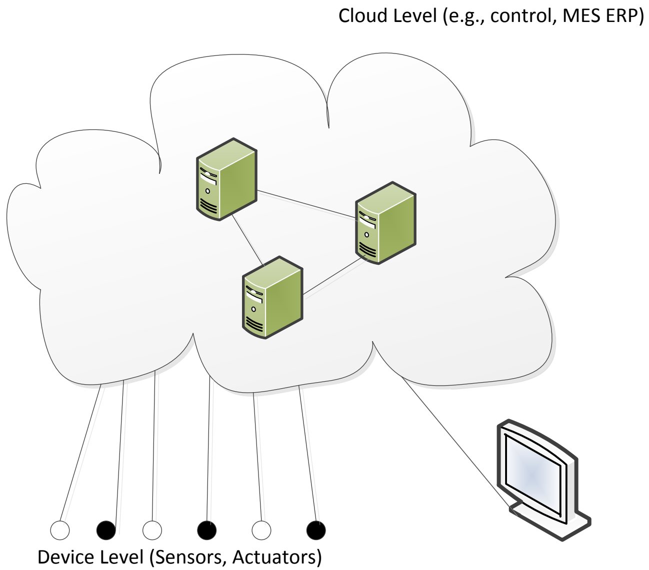
Industrial Internet of Things



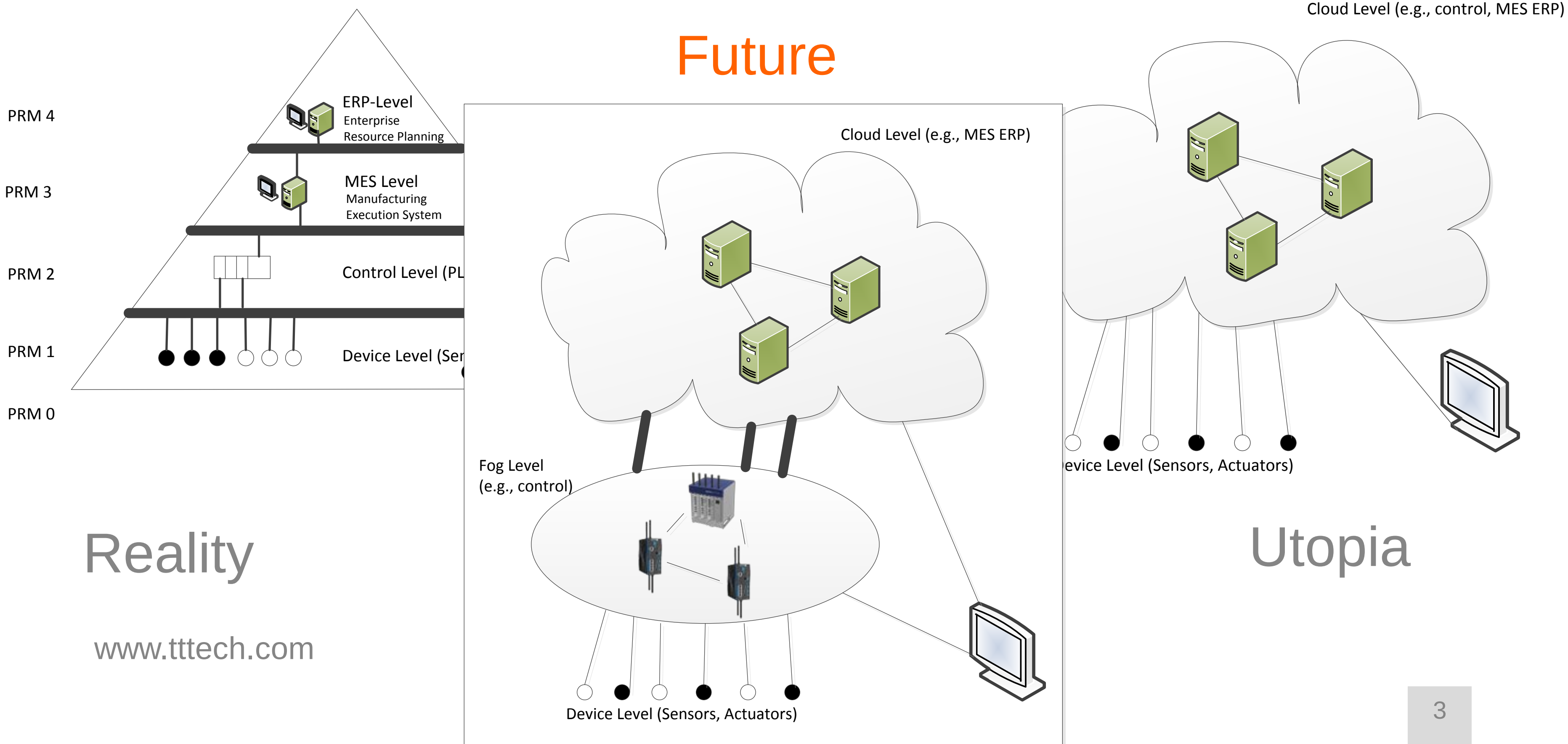
Reality



Utopia

Industrial Internet of Things

Future



Reality

Utopia

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Content

- Fog Computing: A Natural Evolution
- Key Technological Aspects
  - Deterministic Communication
  - Virtualization
- Use Cases in Industrial Automation and Automotive
- Conclusions

Fog Computing:
A Natural Evolution

Cloud Computing

- Many cloud computing use cases
- Office applications like Google Docs are a use case many of us experience every day
- Local devices are used for input/output, actual word processing/storage is done (at least partially) *<u>somewhere else</u>*

Cloud Computing (cont.)

- Geographical decoupling of input/output from processing is not a new concept
- “Powerful” mainframes with “simple” terminals has been and remains a successful architecture
- Cloud computing changed the overall structure of ownership
  - Outsourcing of computation/storage on a large scale became a mainstream business model

Cloud Computing (cont.)

“*There is no cloud, there is just the datacenter of someone else.*” [Anonymous]

Cloud Computing (cont.)

- This outsourcing of computation/storage has certain drawbacks:
  - Details about non-functional aspects of the computation are difficult to assess
  - Non-functional aspects are e.g., real-time response, safety, availability, integrity, reliability, security
- With knowledge about these non-functional aspects, the IoT evolves to the Internet of *Important* Things

Fog Computing

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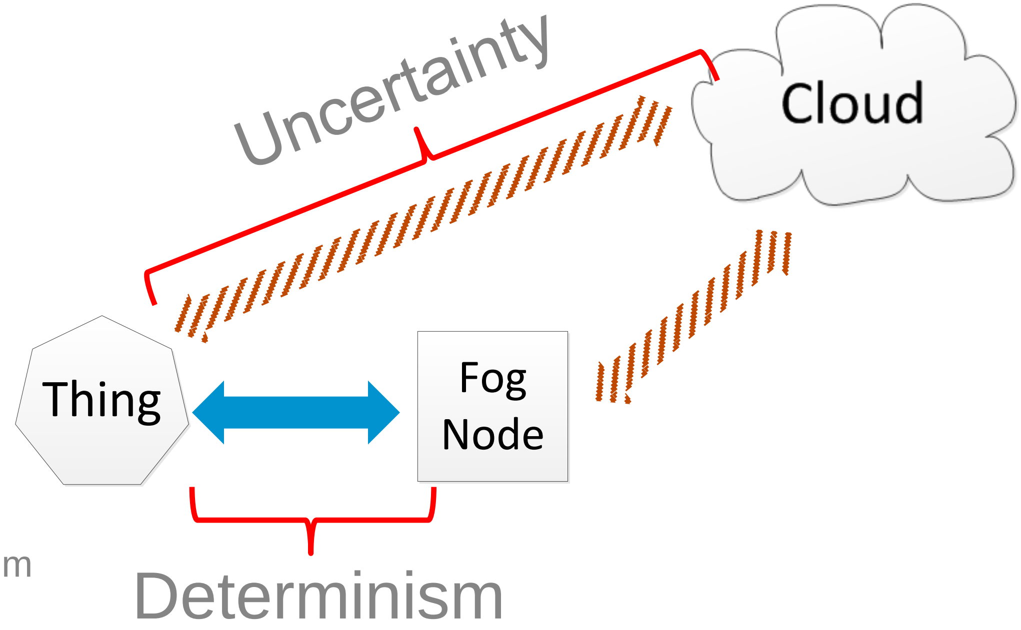
- Fog computing is an architecture approach that provides non-functional knowledge to enable IoIT.



Fog Computing (cont.)

- Fog computing is an architecture approach that provides non-functional knowledge to enable IoIT.

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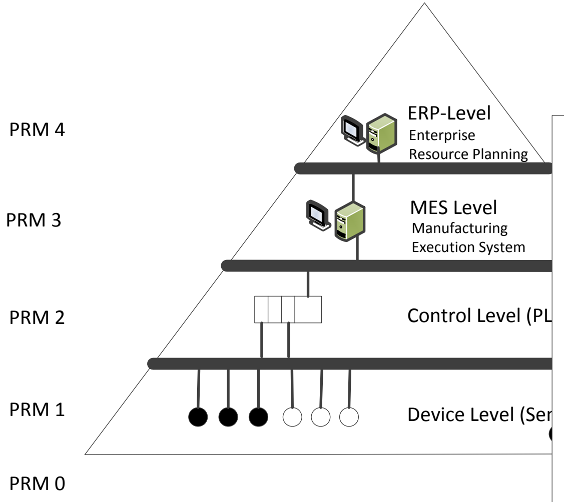
Multiple Components

Modularized & Cross-Industry

Industrial Internet of Things



Reality

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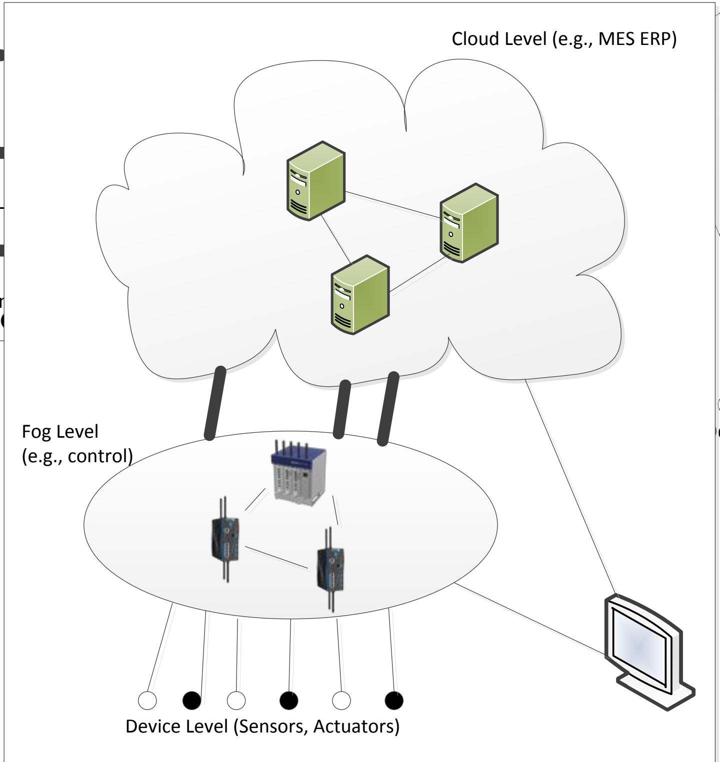

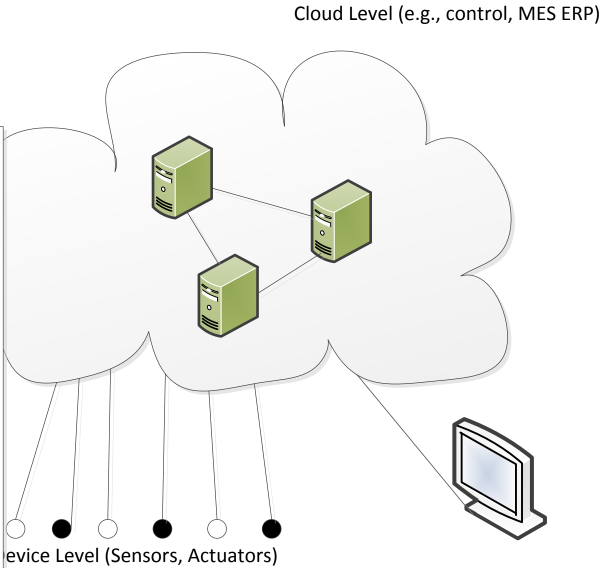

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Key Technological Aspects

Technologies from Two Worlds

Operational Technology
Real-time
Safety
Reliability
Control
Data Acquisition
Human Machine Interface
...

Fog Node

Information Technology
Virtualization
Big Data
Automation
Analytics
Scalability
SDN
Security
...

Fog Node is a platform to realize IT/OT Convergence

Deterministic Communication

- Known upper bounds on latency/jitter/buffer-size/etc. through the network
- Can be achieved by:
  - synchronized communication (TT)
  - constrained unsynchronized communication (e.g., RC)
- Synchronized: Global Time + Communication Schedule
- Unsynchronized: Low Utilization + Network Analysis

IEEE 802.1 TSN Introduction

- IEEE 802 defines standards (used in IT)
- IEEE 802.1 is a working group
- Time-Sensitive Networking (TSN) is a task group (others are, e.g., security) within IEEE 802.1
- For some projects IEEE 802.1 closely interoperates with IEEE 802.3 which maintains and extends the Ethernet PHY and MAC standards

TSN Projects Overview

- .1AS-rev: synchronization improvements
- .1Qbv: time-triggered queues
- .1Qbu: frame preemption and resumption
- .1CB: stream identification and redundancy management
- .1Qca: redundant route configuration
- .1Qcc: configuration and SRP improvements
- .1Qch: cyclic queuing and forwarding
- .1Qci: per-flow policing and filtering
- .1Qcr: asynchronous traffic shaping
- .1Qcs: improved reservation/registration protocol (a.k.a. MRP++)

Deterministic Ethernet Implementation in Detail

AVB (Audio Video Bridging)

TSN (Time-Sensitive Networking)

TTTech's Deterministic Ethernet Implementation

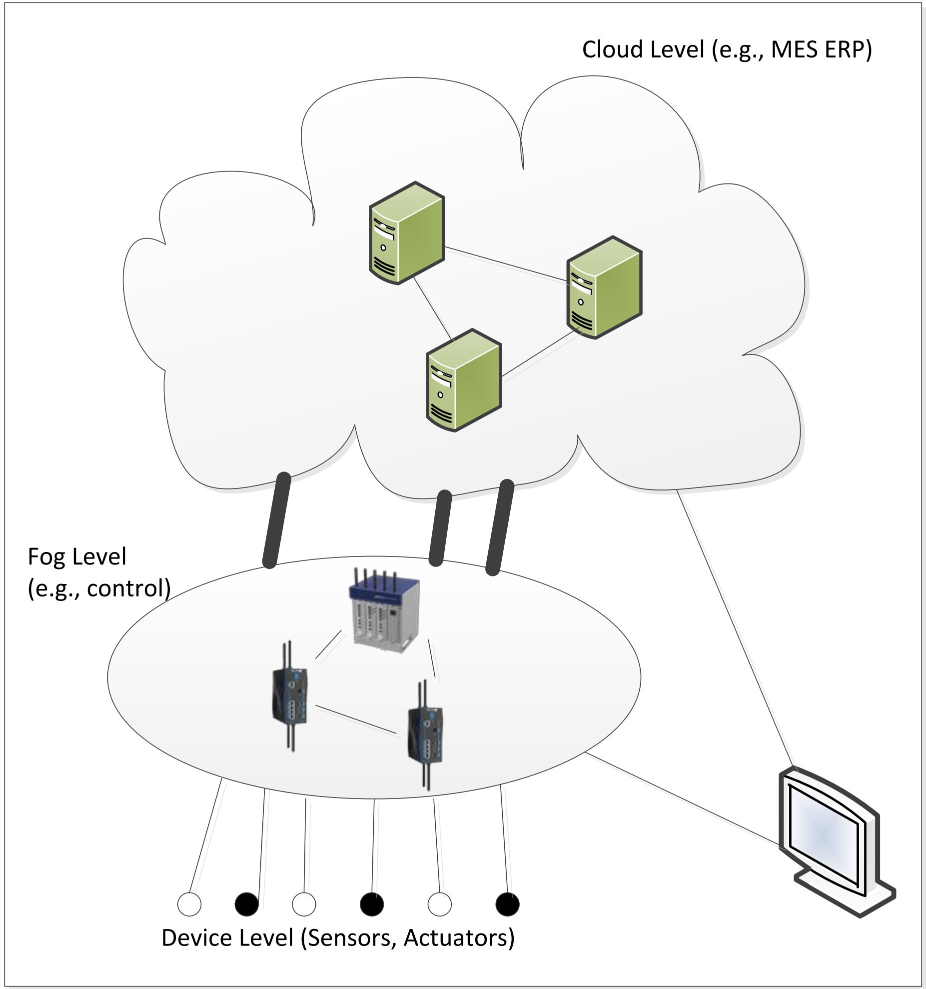
IEEE 802.1D
- Layer 2 Switching

IEEE 802.1Q
- VLAN Aware Bridge
- Packet Priority (QoS)
- 802.1Qat Stream Reservation
- 802.1Qav Credit -Based Shaper

IEEE 802.1AS
- IEEE 802.1AS Software Stack
- Hardware Timestamping

IEEE 802.1TSN
- IEEE 802.1Qbv Time-Aware Shaper
- IEEE 802.1Qbu Preemption
- IEEE 802.1CB Redundancy
- IEEE 802.1Qci Policing
- …

Fully Scheduled Networks
- SAE AS6802 Fault-Tolerant Clock Sync.
- Time-Triggered Shaper



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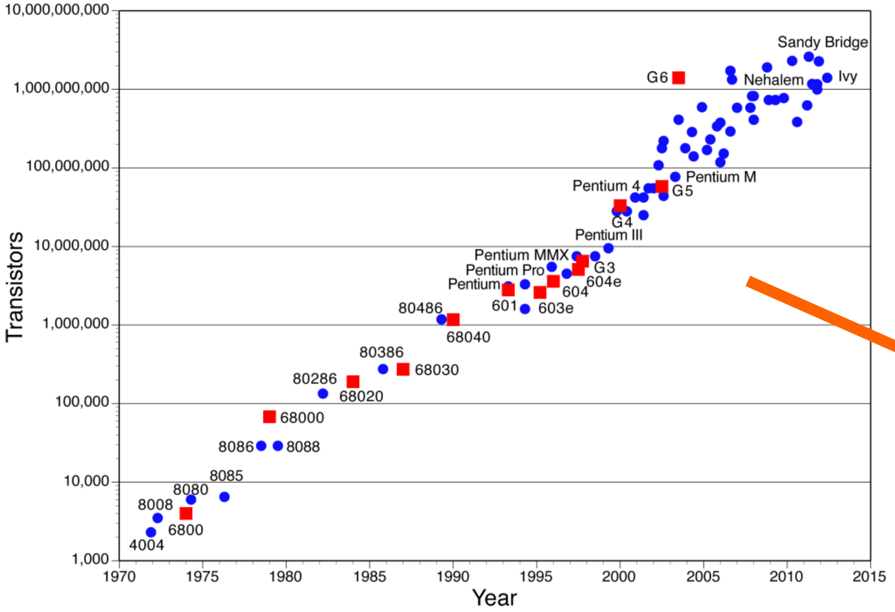
Deterministic Ethernet decouples data generation (i.e., sensor data) and data application (e.g., actuators) from the actual control.

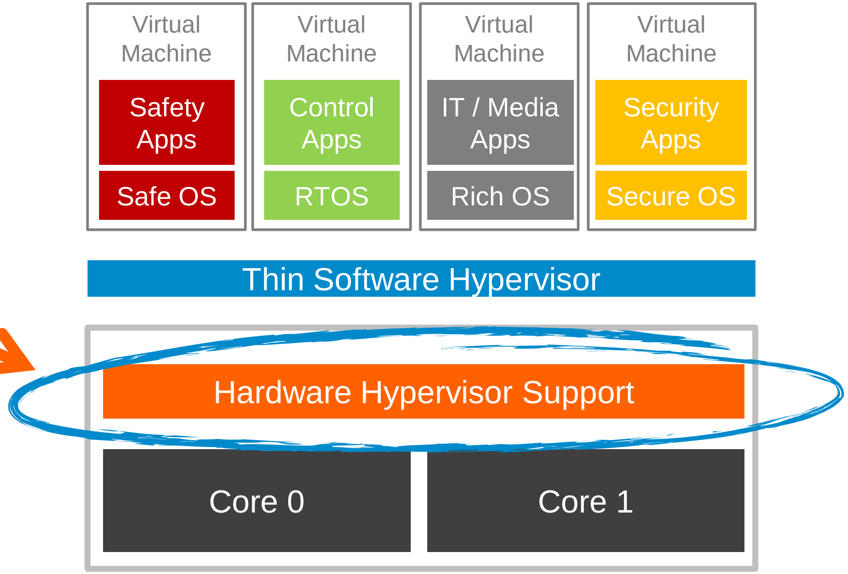
Virtualization

Moore's Law Alive and Well

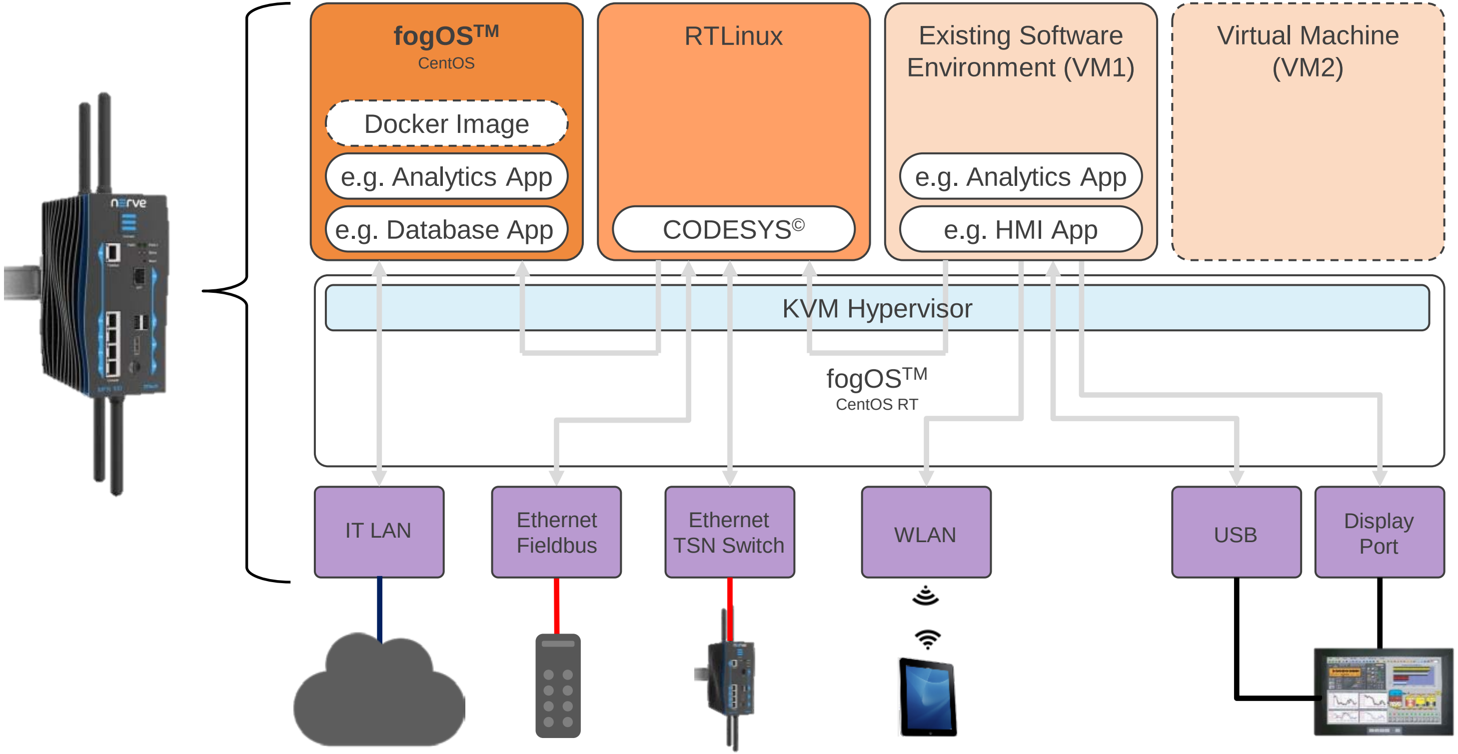
Heterogeneous Multi-Core



Hardware Supported Virtualization at Chip Level Possible



Software Architecture Incl. fogOS™

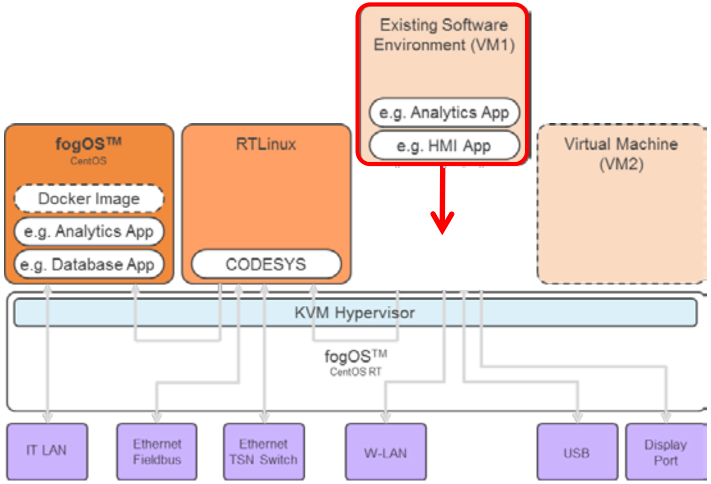


Use Case Overview

- New value from installed machines
- Reduced maintenance overheads
- Centralized software deployment
- Access rights to machine data
- Improved machine optimization
- Wider machine services offering

New Value from Installed Machines

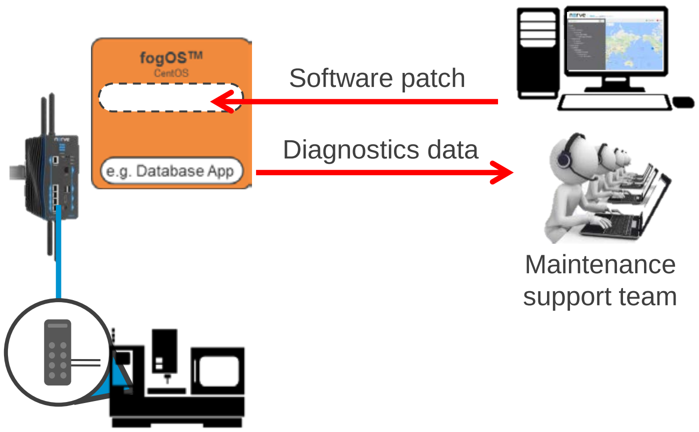
Challenge: Installed machines equipped with ageing hardware that cannot host latest software and services



- Fast and easy migration of legacy software to fog node
- Host legacy PC based applications as virtual machines
- Add newest applications to installed machines in parallel to legacy software
- Access data from installed machines and offer latest services to all customers

Reduced Maintenance Overheads

Challenge: Difficult to plan costs and duration of maintenance, especially at remote customer locations

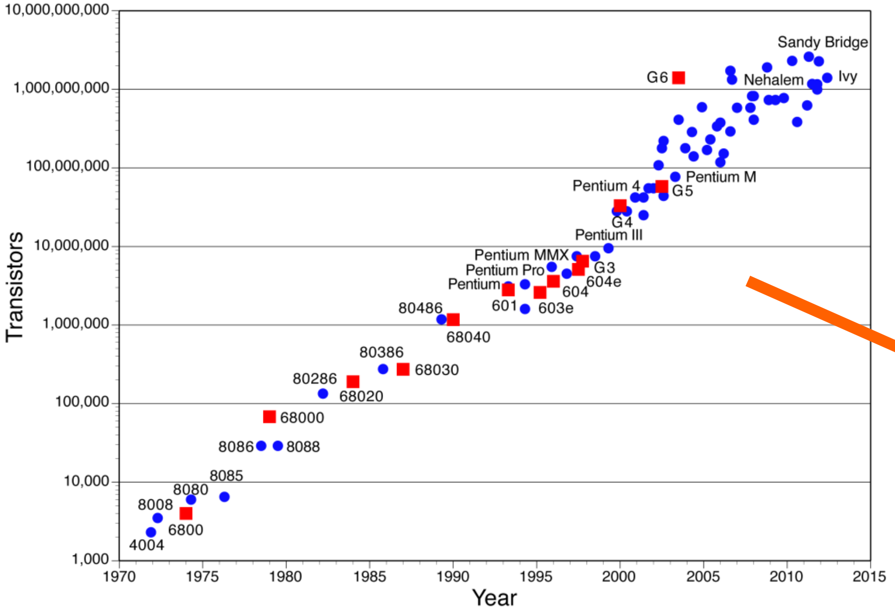


- Detect and resolve common errors remotely
- No need for additional user management system for remote maintenance
- Consolidate engineering expertise and avoid excessive travel costs
- Plan spare parts inventory better and predict maintenance demands

Towards Distributed MILS

Moore's Law Alive and Well

Heterogeneous Multi-Core



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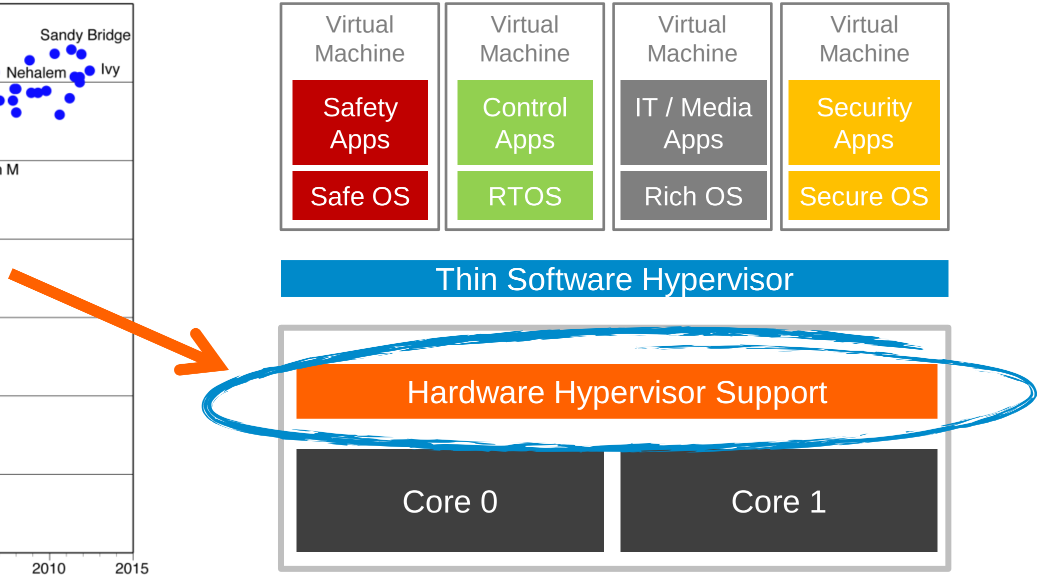

Towards Distributed MILS (cont.)

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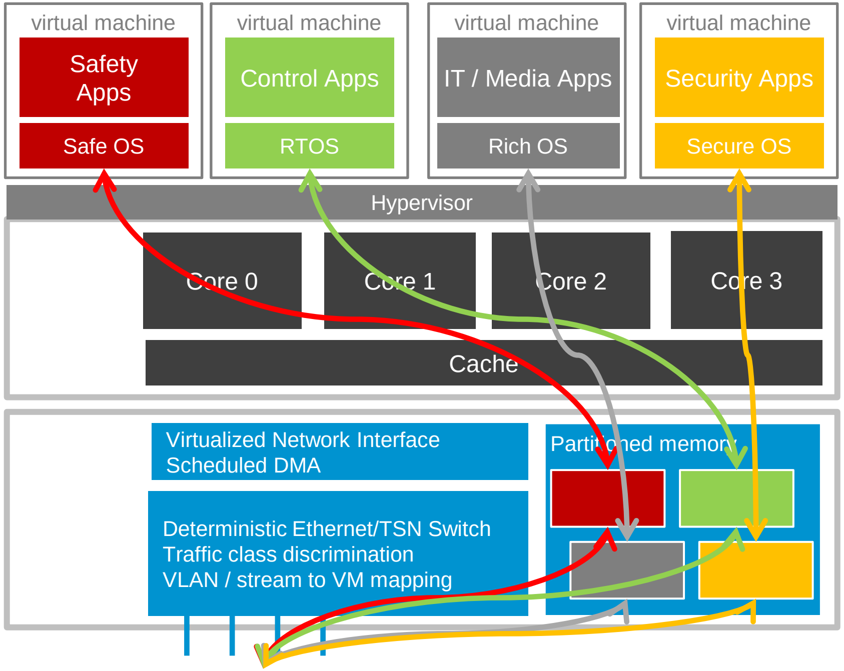
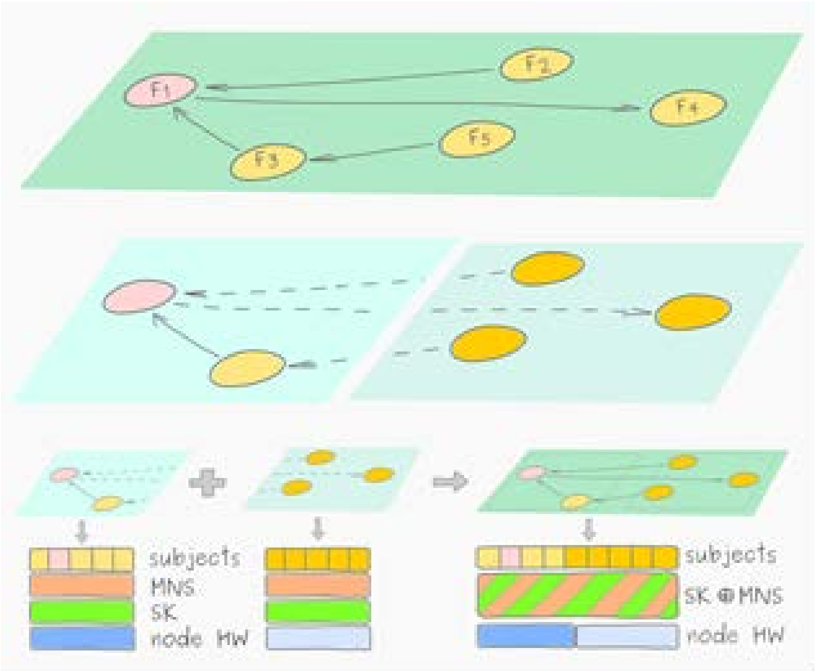
- VLANs to memory partition mapping fully supported at the hardware level
- Memory partitions are mapped to virtual machines
- Guaranteed bandwidth for each VLAN
- Guaranteed application-to-application latency with minimum jitter



Towards Distributed MILS (cont.)

- Separation kernel can be combined with a MILS network subsystem (MNS)
- The MILS policy architecture can then span not only the resources of a single node, but multiple MILS nodes (hence Distributed MILS)
- A distributed MILS system can be expressed by a policy architecture realized as a set of configured MILS nodes



Conclusions

Conclusions

- The Internet of Things already exists today
- The interconnection of critical and important things requires non-functional information (such as real-time response and reliability numbers)
- Fog Computing is a new architecture layer for the infrastructure of the IoT and enables the

Industrial Internet of Things

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