Ensuring Reliable Networks TTTech

Consolidation of IT and OT based on Virtualization and Deterministic Ethernet

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Smart Factories of the Future

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- will combine IT (information technology) and OT (operations technology) in new and innovative ways.
- For example,
  - big data may help to find and to continuously update optimal configuration sets,
  - IT-like SW-update procedures may increase production flexibility (e.g., mass customization).

A Thing

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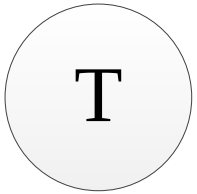
A not very smart thing



Embedded System
incl. I/O

Smartness by Internet of Things

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The “IT perspective”

Massive
Compute/Storage

Embedded System
incl. I/O

(i)nternet of Smart Things

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The “CPS (OT) perspective”

Massive
Compute/Storage

Embedded System
incl. I/O

Network Edge Computing

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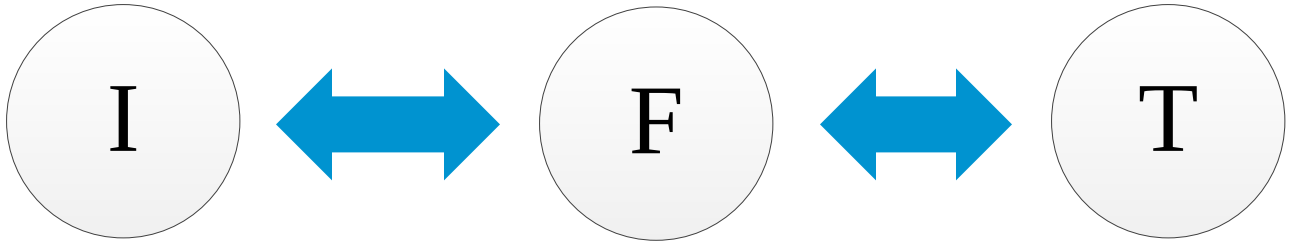
How about a third “IT/OT” perspective?



Massive Compute/Storage

Fog Node (local)

Embedded System incl. I/O

Network Edge Computing

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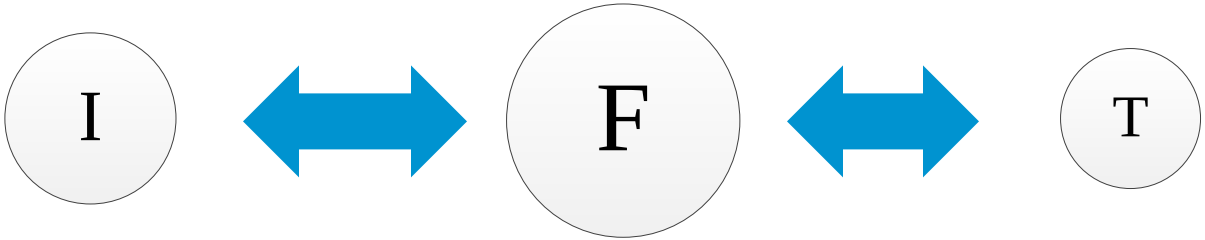
Enables Communication/Computation Tradeoffs



Massive Compute/Storage

Fog Node (local)

Smart I/O

Network Edge Computing

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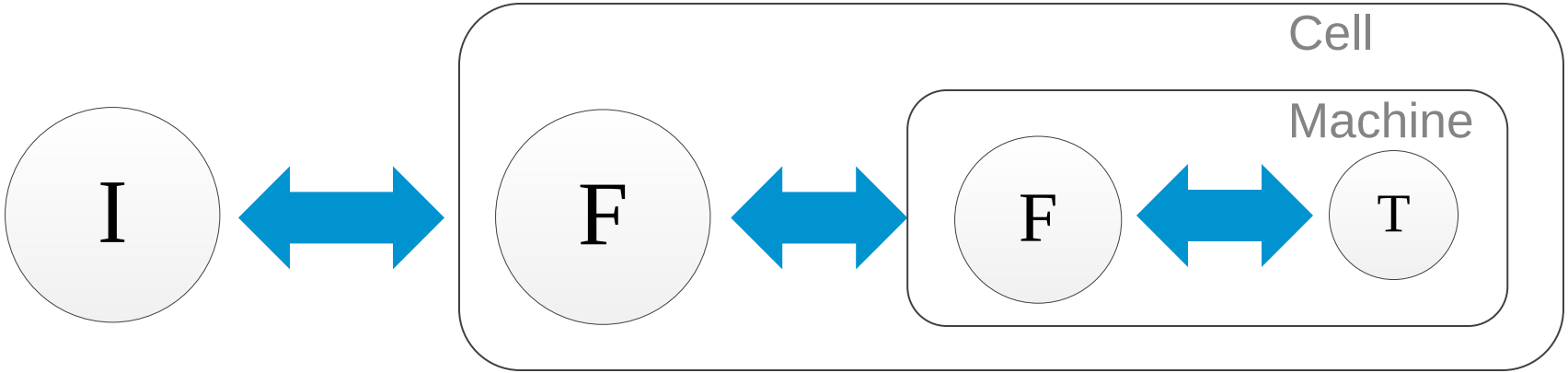
And it scales.



Massive Compute/Storage

Fog Node (local)

Fog Node (local)

Smart I/O

Network Edge Computing

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And it's real.

Massive Compute/Storage

Fog Node

Embedded System incl. I/O

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IT and OT Convergence in Industrial Automation

The Fog Node: Enabling Converged and Additional Functionality for Industrial Automation

ERP/MRP System

Manufacturing Execution System

Cell Controller

Robotics Controller And Visualization

PLC System

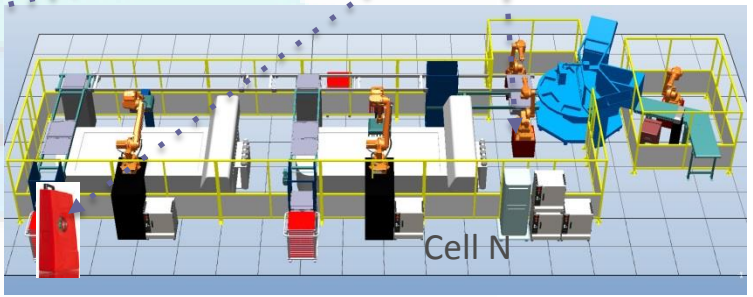
Machine Vision and Bar Code Reader

Converging Functionality

Small Data

Nebbiolo Fog Node

Adding Functionality



Motivation

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- Position Network-Edge Computing as a new architecture paradigm for factory automation (and other industrial areas).
- Let the fog node mediate between the IT perspective and the OT perspective.
- Let the fog node be the means to integrate IT and OT.
- At some point in the integration process the fog node may even become obsolete.

Content

- ✓ Motivation
- Network Edge Computing
- Key Technology I: Virtualization
- Key Technology II: Deterministic Communication
- Example Use Cases
- Conclusions

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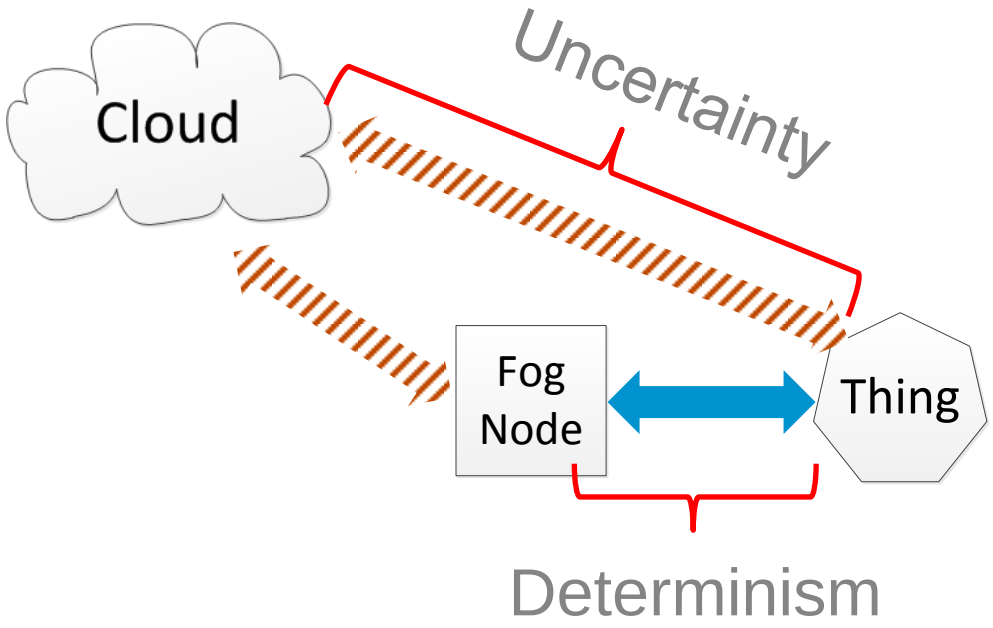
Network Edge Computing

Network Edge Computing



Technologies from Two Worlds

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

Fog Node

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

Fog Node is a platform to realize IT/OT Convergence

Hardware Competitive Landscape

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Nebbiolo Technologies 3 Slot System: = 20-30 Industrial PCs !

Nebbiolo Technologies 3 Slot System: = ~15-20 IoT Gateways !

Data center Servers or Micro-Servers

Industrial PC

Real-time, High-availability, Industrial Fog Node Virtualizing and consolidating , multiple PLCs and Industrial PCs (SBCs)

IoT Gateway

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Fog Node Hardware Components

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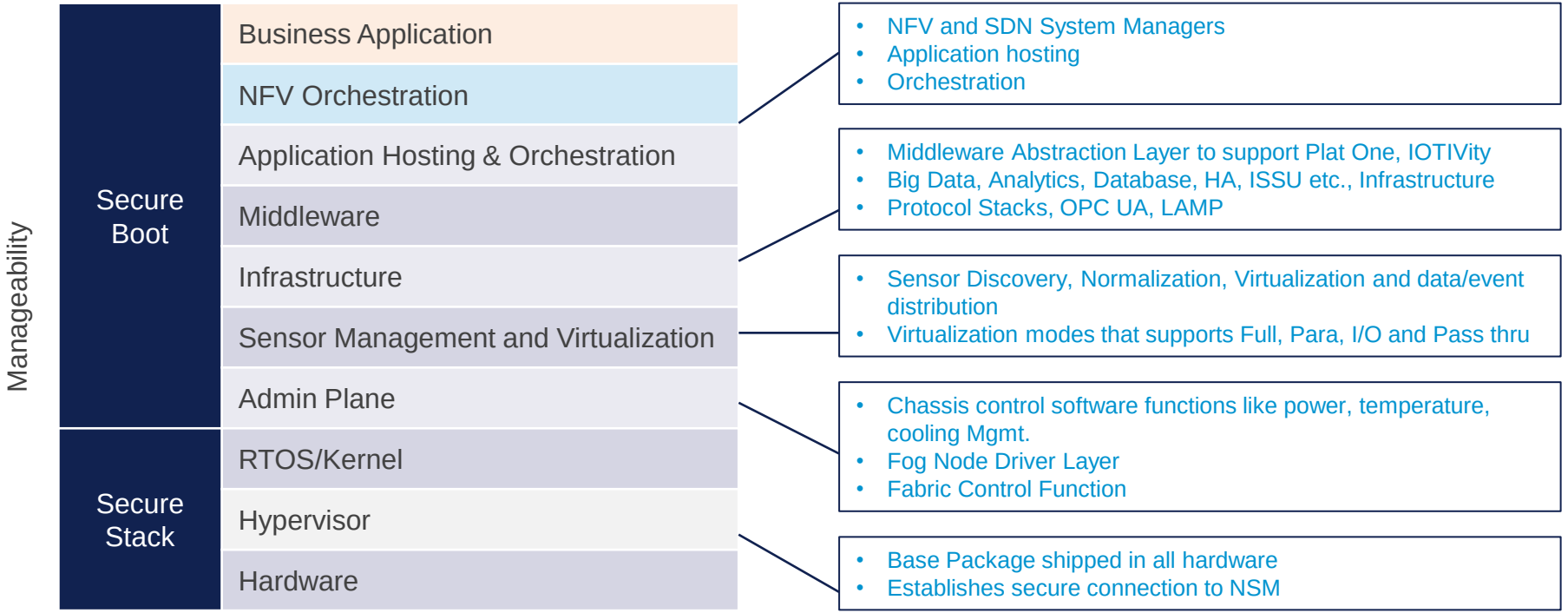
- CPU complex
  - Range of X86 CPUs [Atom, Core (i3, i5, i7)]
  - Support for Skylake in near future
  - TPM chip for Trusted Boot support
  - 4GB to 16GB memory
- Storage
  - 64GB to 1TB SSD/SATA in M.2 form factor
- GPU
  - Range of GPU capabilities supported with Auxiliary card
- Internal Networking
  - 10 Gbps SerDes capable
- Architecture supports following I/O:
  - Gigabit Ethernet, 10Gbe
  - legacy protocols
  - Deterministic Ethernet
- WiFi
  - 802.11b/g/n, 802.11ac, BTLE, LoRa, Zigbee
- Cellular
  - 4G LTE
  - GPS

Fog Node Software Components



Two Key Enabling Technologies

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- Virtualization
  - to share the hardware resources between multiple Things,
  - with known and bounded interference.
- Deterministic Networking
  - to spatially separate I/O from computation,
  - to share the physical network between multiple Things,
  - with known and bounded interference.

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Virtualization

Virtualization

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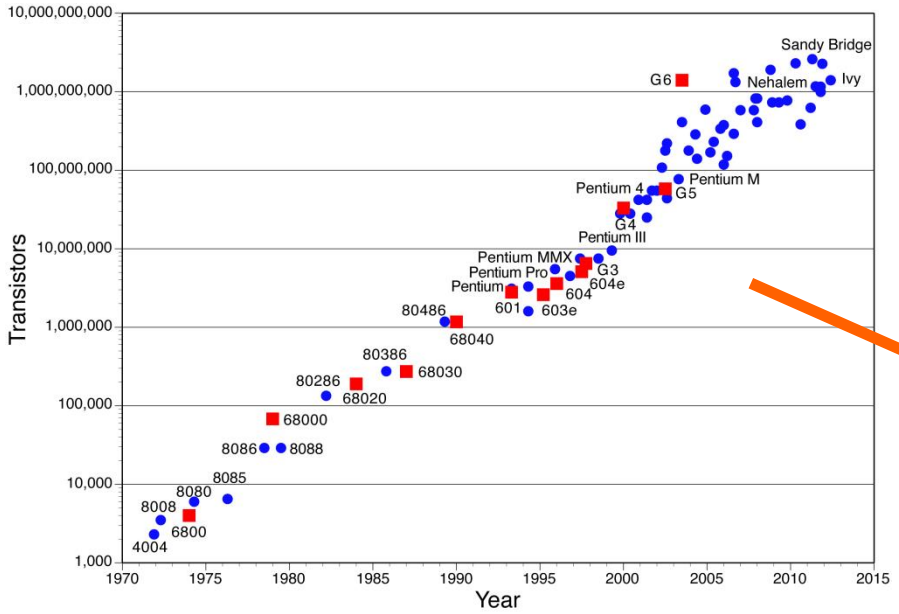
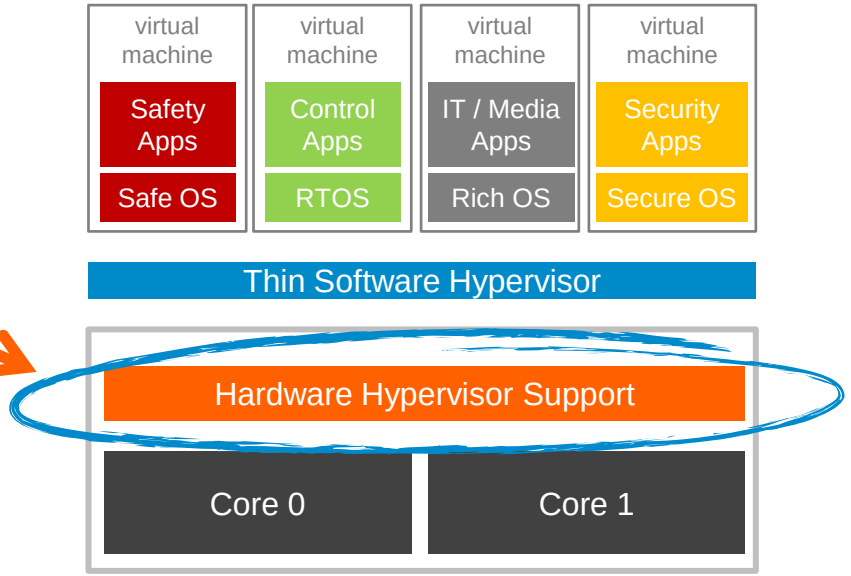
Moore's Law Alive and Well
Heterogeneous Multi-Core



Hardware Supported Virtualization at Chip Level Possible



Hardware Supported Virtualization at the Chip Level is Essential for Cloud and Fog Architectures

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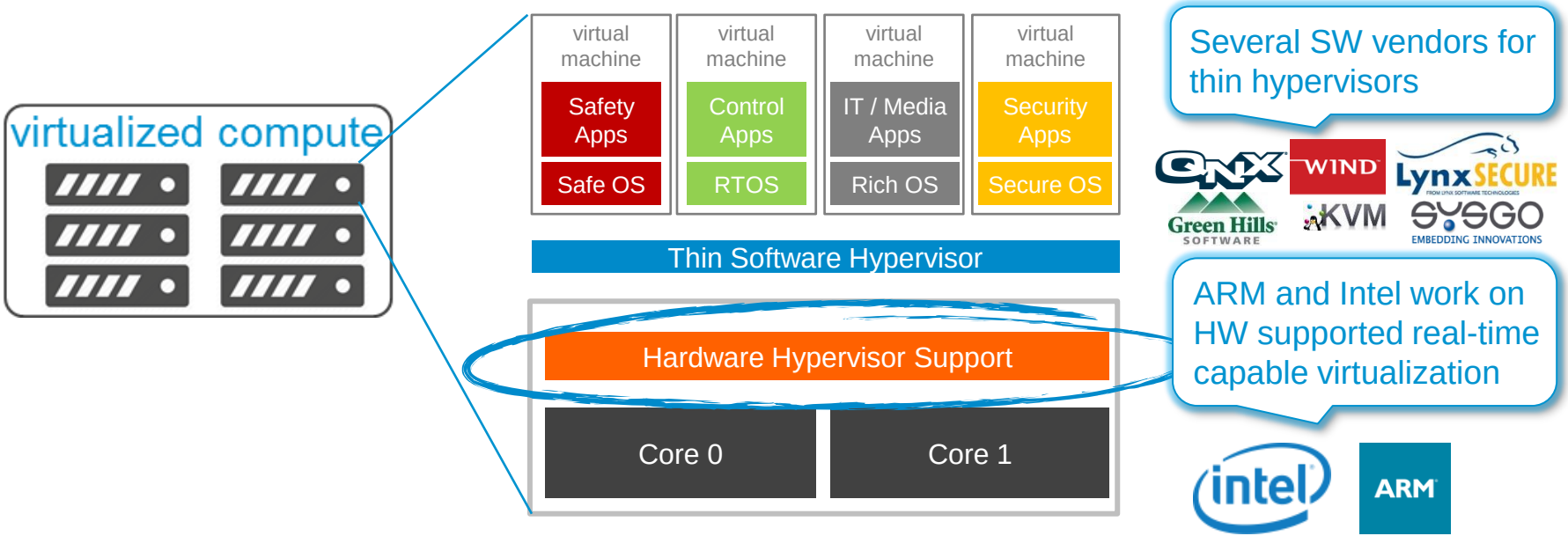

Combining virtualized computing with virtualization communication enables

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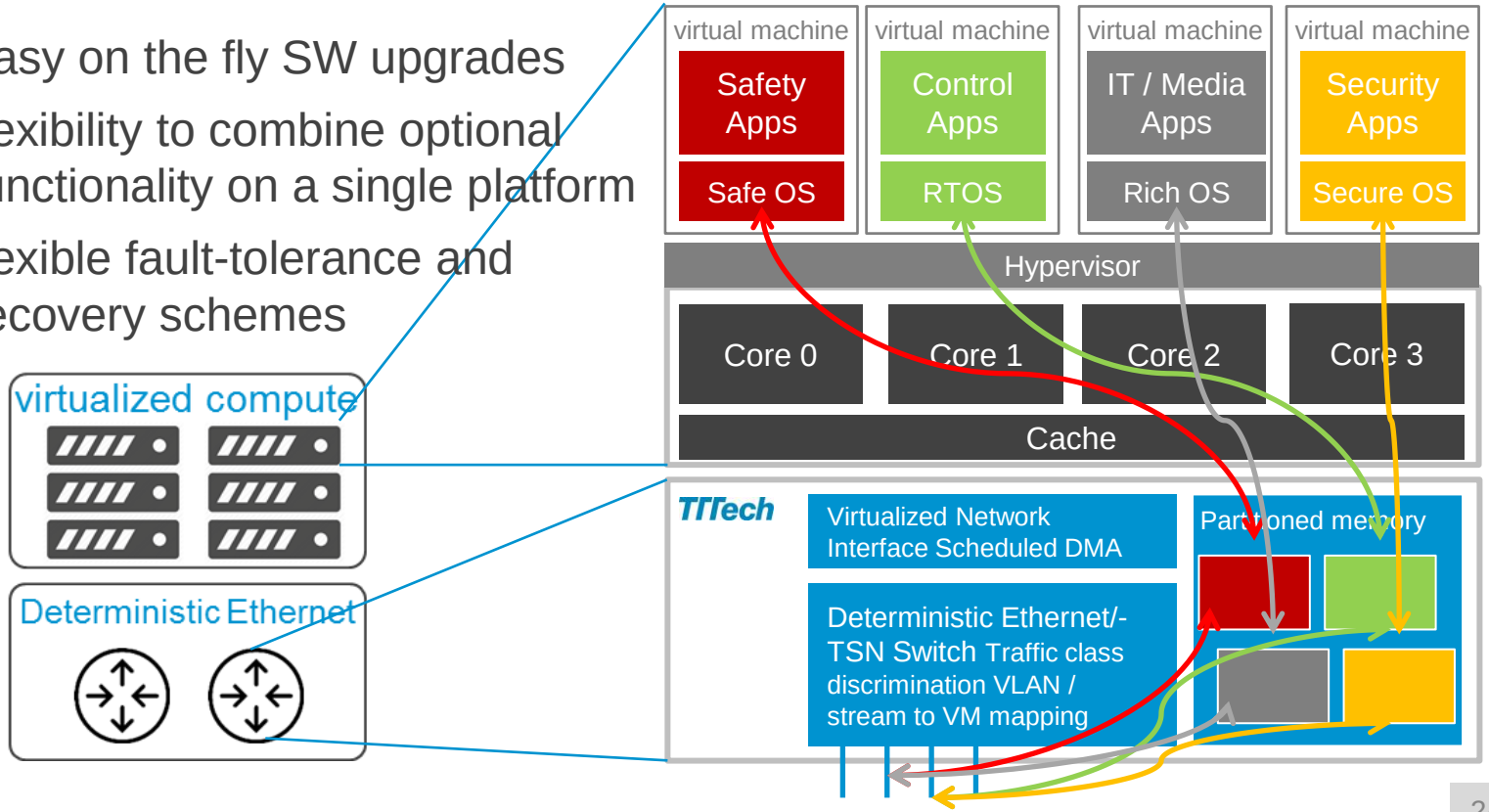
- easy on the fly SW upgrades
- flexibility to combine optional functionality on a single platform
- flexible fault-tolerance and recovery schemes



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Deterministic Communication

Deterministic Communication

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- 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

Network Virtualization based on Deterministic Ethernet

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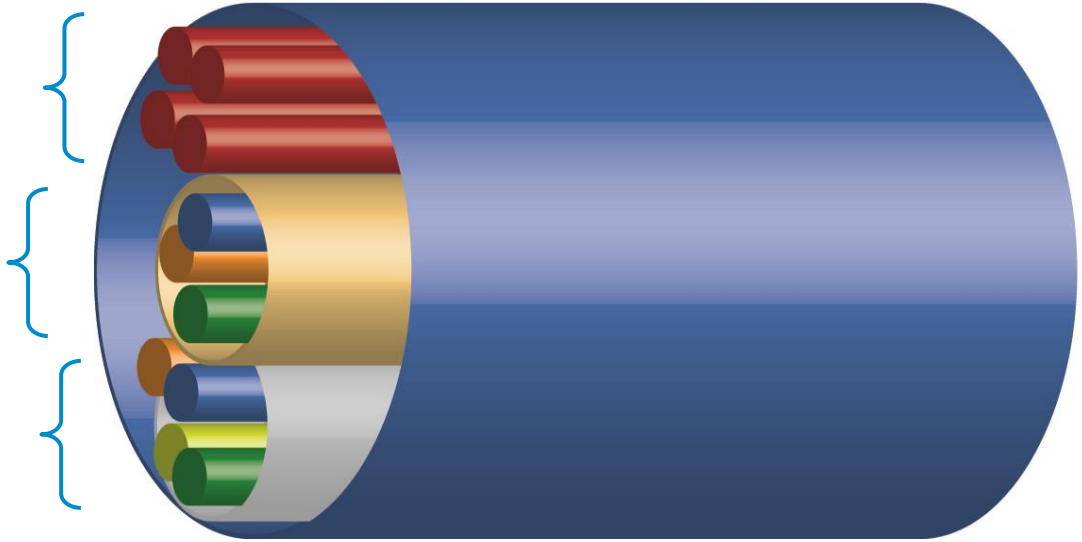
Synchronous Traffic
- Safety and real-time control
- Steering, braking, …

Streaming
- Audio
- Video

Standard Ethernet Traffic
- Diagnostic over IP
- Download and Flash

Many Virtual Links on a Single Cable



IEEE 802.1 TSN Introduction

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- IEEE 802 defines standards (used in IT)
- IEEE 802.1 is a working group
- IEEE 802.1 Time-Sensitive Networking (TSN) is a task group (others are, e.g., security)
- Members are from leading IT network companies, but also from industrial and automotive.

TSN – Time-Sensitive Networks

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802.1ASbt Timing and Synchronization: Enhancements and Performance Improvements

802.1Qbv Enhancements for Scheduled Traffic: a basic form of time-triggered communication

802.1Qbu Frame Preemption: a mechanism that allows to preempt a frame in transmit to intersperse another frame.

802.1Qca Path Control and Reservation: protocols and mechanisms to set up and manage the redundant communication paths in the network.

802.1CB Frame Replication and Elimination for Reliability: to eliminate redundant copies of frames transmitted over the redundant paths setup in 802.1Qca.

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Dependability Entering Mainstream IT Networking Standards (IEEE 802.1)

64th Meeting of the IFIP 10.4 Working Group on Dependable Computing and Fault Tolerance

Visegrád, Hungary, June 27-30, 2013

TSN projects overview (Jun/2016)

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- .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++)

TSN projects status (Mar/2016)

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Functional Complete

Standard	Current Version	PAR Req/Appr.	Start TG Ballot	Start WG ballot	Sponsor Ballot	RevCom	
~~802.1Qbv~~	~~D3.1~~	~~15-May-12~~	~~2-Dec-13~~	~~4-Sep-14~~	~~17-Jul-15~~	~~published Mar/17, 2016~~	
802.1AS-rev	D2.0	10-Sep-11	20-May-13				
802.1CB	D2.3	1-Mar-13	3-Nov-14	17-Jul-15			
~~802.1Qca~~	~~D2.1~~	~~5-Dec-12~~	~~9-Aug-13~~	~~5-Aug-14~~	~~12-Mar-15~~	~~published Mar/11, 2015~~	
802.1Qbu	D3.1	15-May-12	28-Jul-14	11-Dec-14	17-Jul-15	on hold until .3br is ready (likely in May/2016)	
802.1Qcc	D0.6	21-Oct-13	1-Dec-14	17-Mar-16			
802.1Qch	D0.1	1-Nov-14	17-Mar-16				
802.1Qci	D1.1	12-Mar-15	12-Nov-15	17-Mar-16			
802.1Qcr	PAR	17-Mar-16					Urgency-Based Shaper
802.1Qcs	PAR Development	17-Mar-16					MRP++

Draft ready

External Review

Deterministic Ethernet

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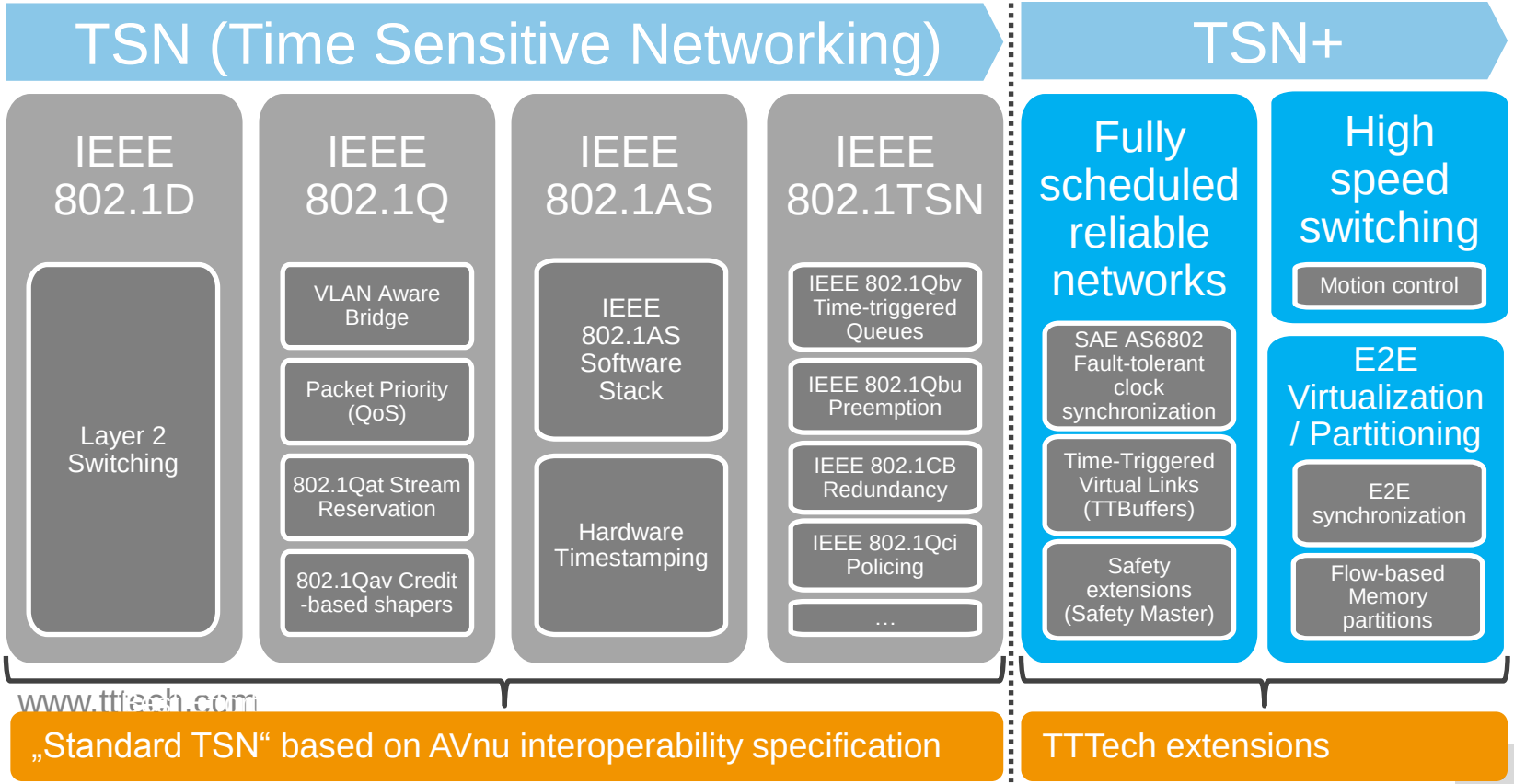

Deterministic Ethernet Evolution

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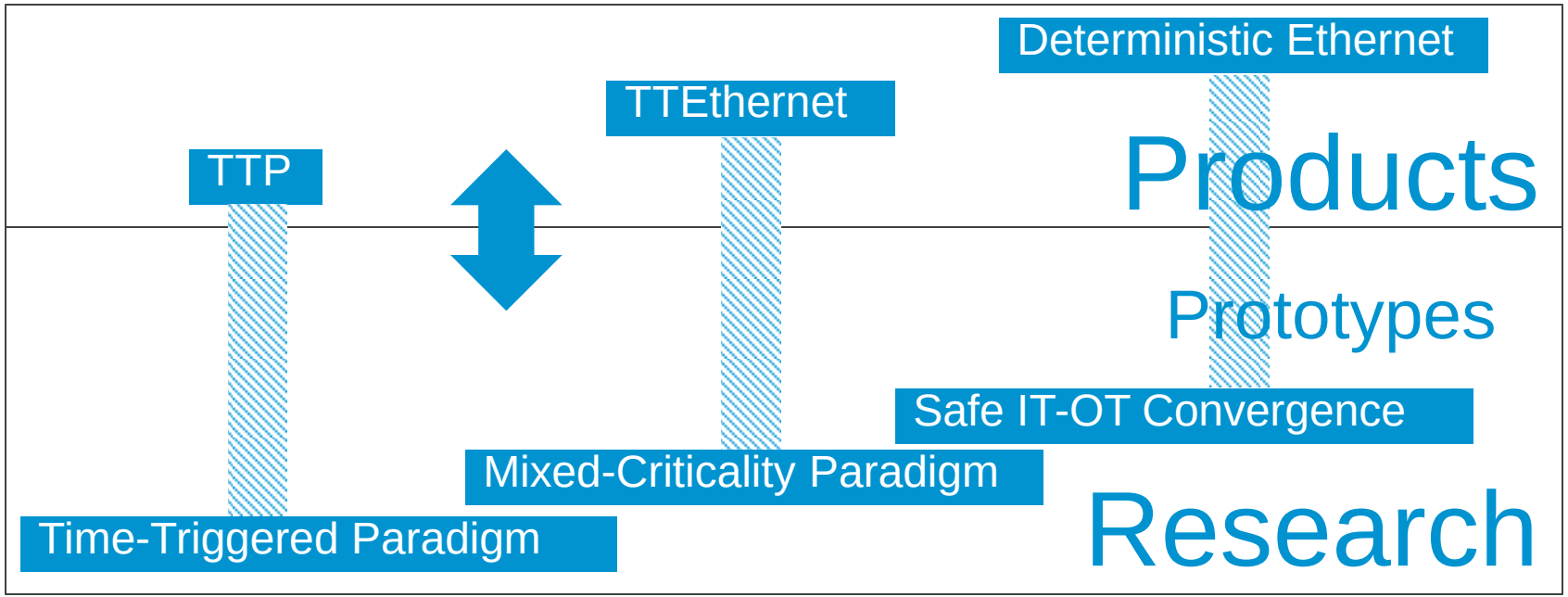
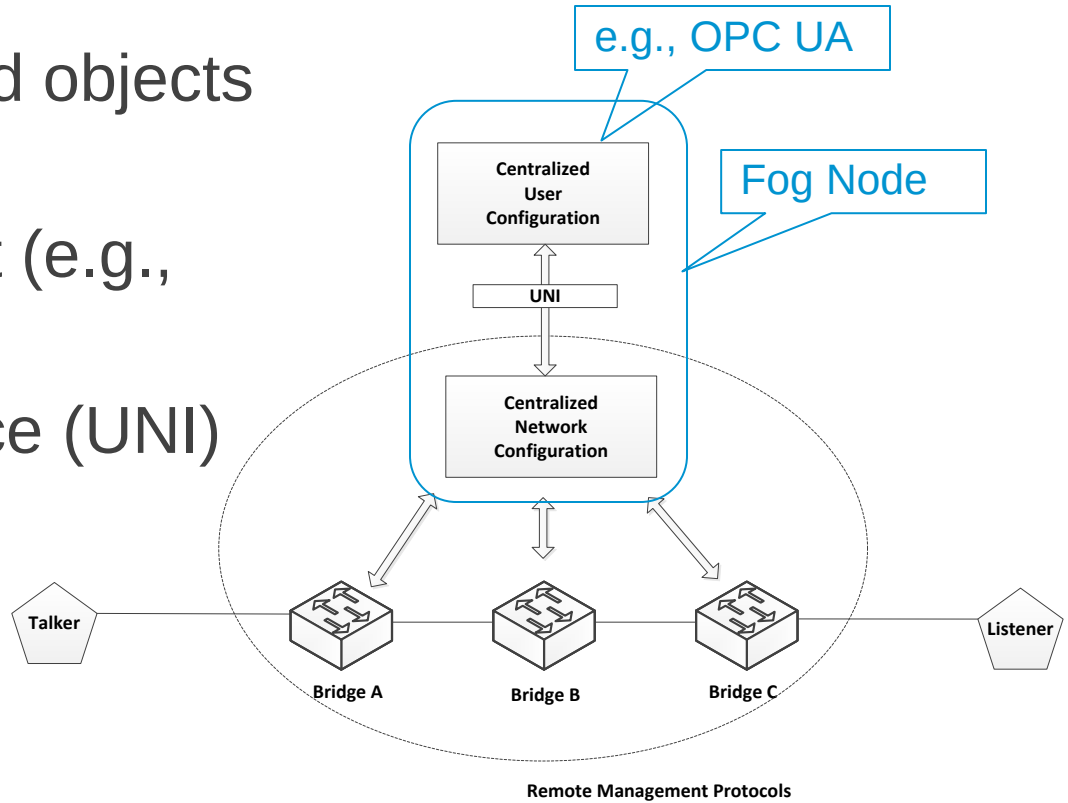


TSN Configuration

- TSN defines managed objects (in YANG).
- Remote management (e.g., NETCONF) support
- User/Network Interface (UNI)



Network Management Proposal from Siemens

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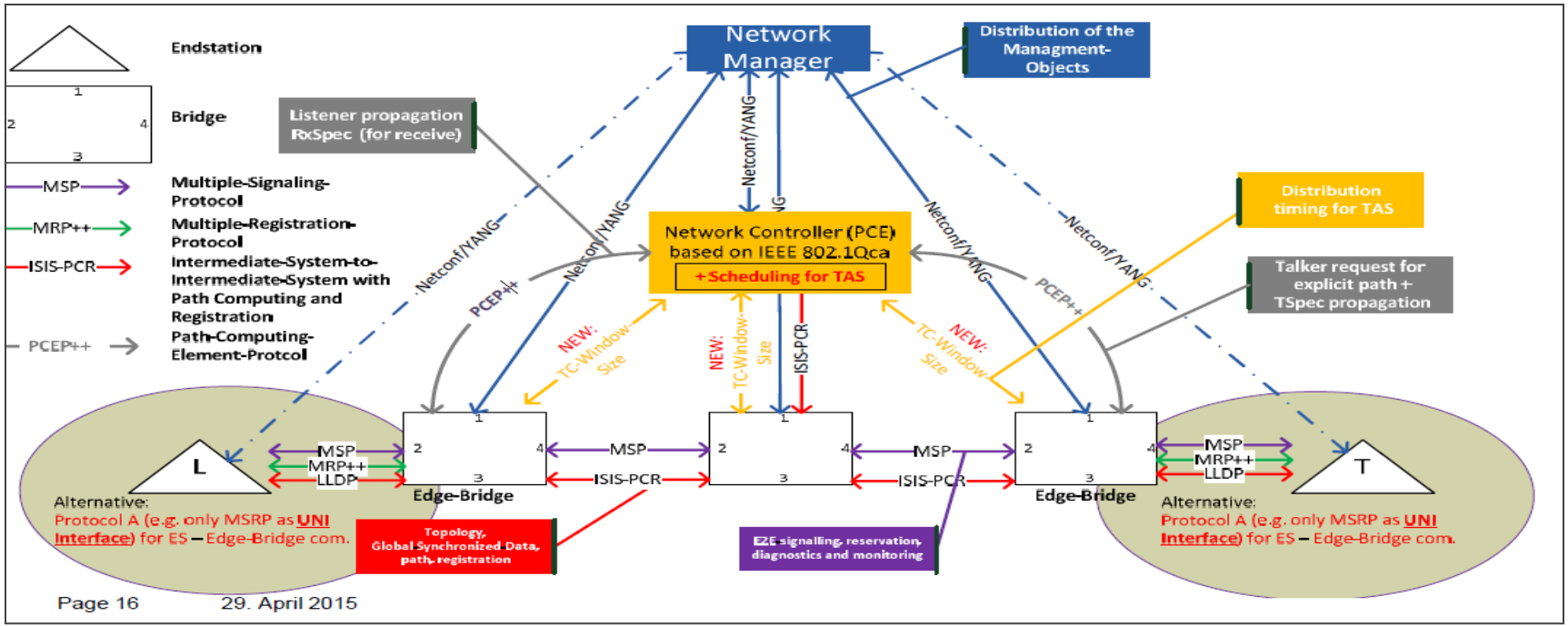
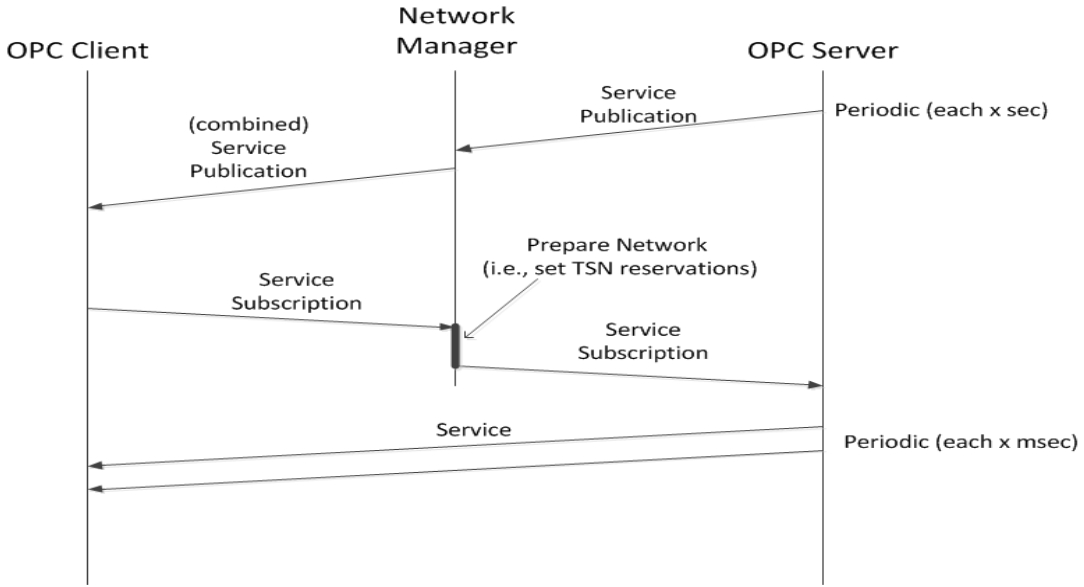


http://ieee802.org/1/files/public/docs2015/cc-goetz-MRPv2-MSP-v10.pdf

Centralized OPC UA & TSN integration

- Server publishes its services only to the Network Manager
- Network manager either forwards service publications or provides combined service publications for several servers
- Client subscribes by responding to the network manager
- Network manager prepares the network, when completed forwards service subscription to the server



Wide Area Deterministic Networks

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- IEEE 802.1 Time-Sensitive Networking (TSN) targets primarily layer 2 networks.
- IETF DetNet is introducing deterministic networking to layers 3 and above.
  - Current solutions are acceptable for VoIP but not for more demanding applications.

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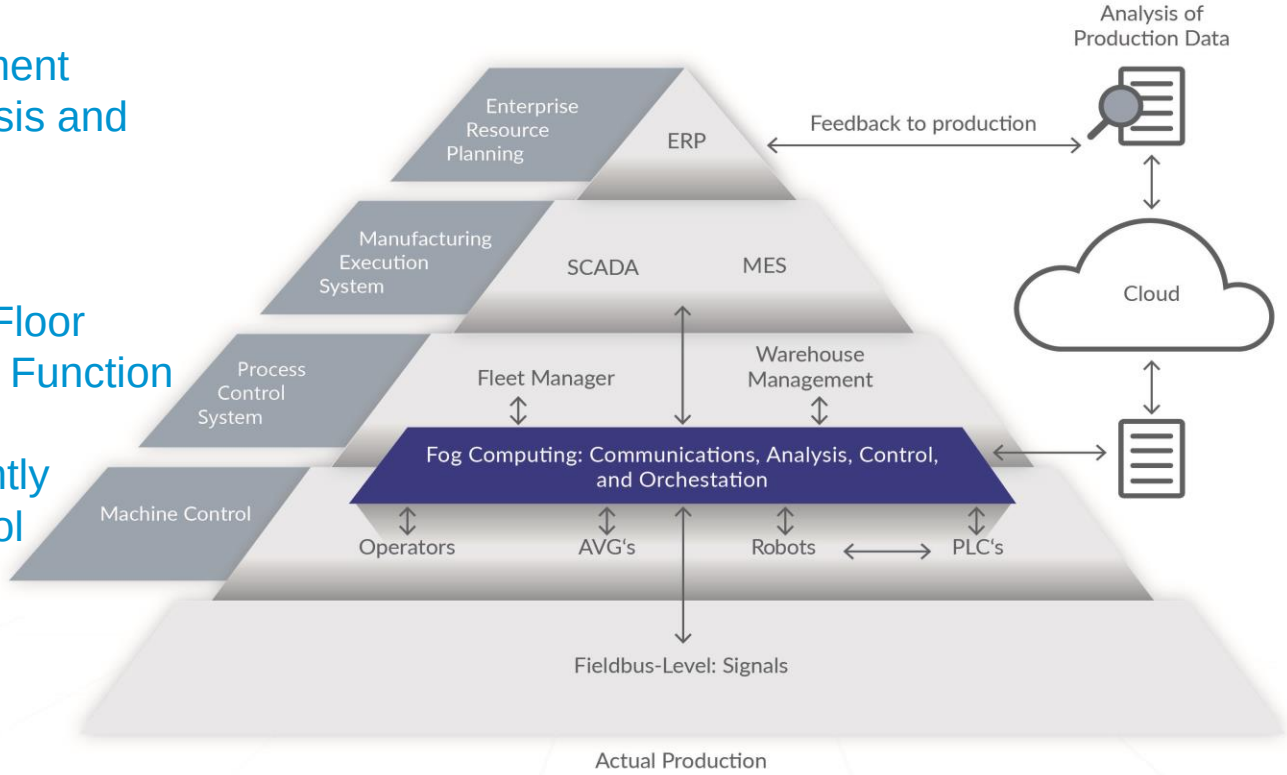
Use Cases

Industrial Use Cases

1. Factory Fleet Management
2. Data Acquisition, Analysis and Visualization
3. Application Hosting
4. Software Upgrade
5. Consolidation of Shop Floor Equipment via Network Function Virtualization
6. Consolidation of Currently Siloed Industrial Control
7. Flexible Factory



Automotive Use Case I

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The traffic junction as a rich point of:

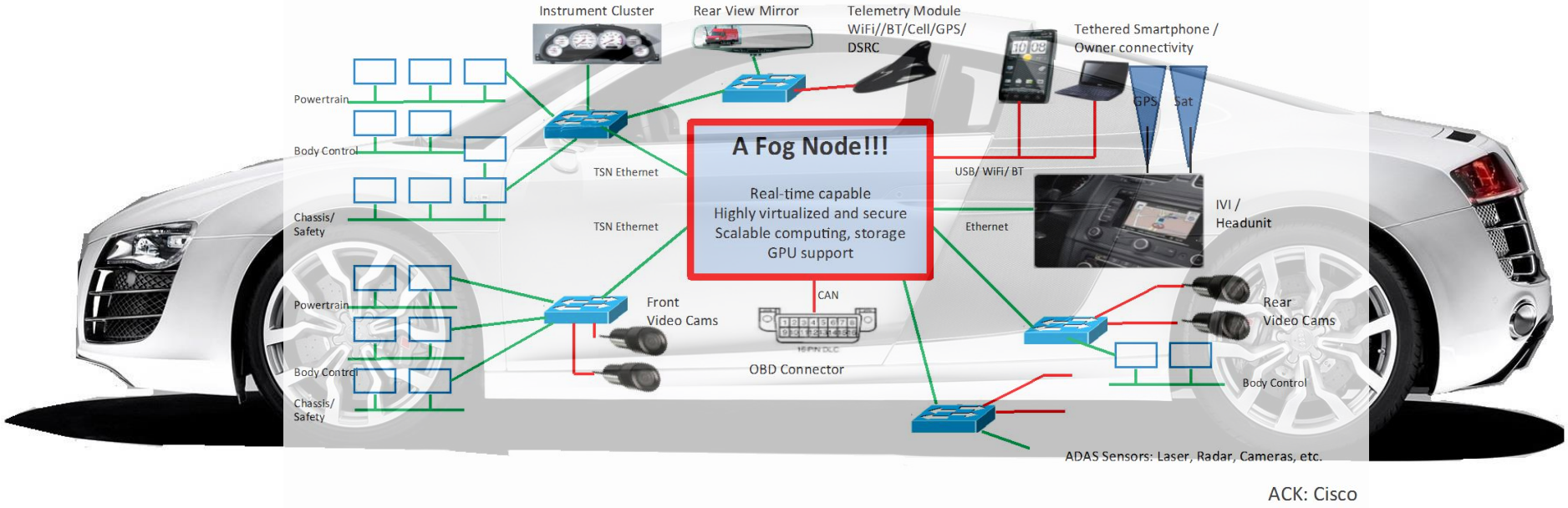
- Communications
- Computing
- Storage

Vehicle Detection

Perfect Position for a Fog Node!!!

Key Functional Location in Smart Cities!!!

Automotive Use Case II



ACK: Cisco

An Early Fog Node

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Sensor Fusion

Strong CPU Power

TT Ethernet moving to TSN

GPUs

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Conclusions

Conclusions

- IT products and concepts are becoming more and more available for use as operations technology (OT).
- An intermediate layer between the cloud and the Thing seems to be a promising approach.
- We call this intermediate layer network-edge computing.
- Prototypes are ready and have been showcased in industrial settings.

Some Research Challenges

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- Real-time control in an virtualized environment.
- Efficient safety certification of mixed-criticality platforms (like the fog node).
- Cybersecurity and security certification.
- Constraints:
  - there are many standards that we need to follow and
  - most of the standards solutions are imperfect.

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