nebbiolotechnologies
fog computing pioneers

IEEE 5G SUMMIT

Fog Computing, its Applications in Industrial IoT, and its Implications for the Future of 5G

Flavio Bonomi, CEO and Co-Founder, Nebbiolo Technologies
IEEE 5G Summit, Honolulu, May 5th, 2017

Agenda

- Fog Computing and 5G: High Level Introduction
- Architectural Angles in “Fog” with Relevance to 5G
- Fog Computing and 5G: Natural Partners for the Future of Industrial IoT, with Applications
- Nebbiolo Technologies: Brief Introduction
- Conclusions

The Pendulum Swinging Back: A Renewed Focus on the Edge of the Network, Motivated by the Network Evolution, 5G and IoT

Fog Computing
Mobile Edge Computing
(Modern, Real-Time Capable) Edge Computing
Real-Time Edge Cloud

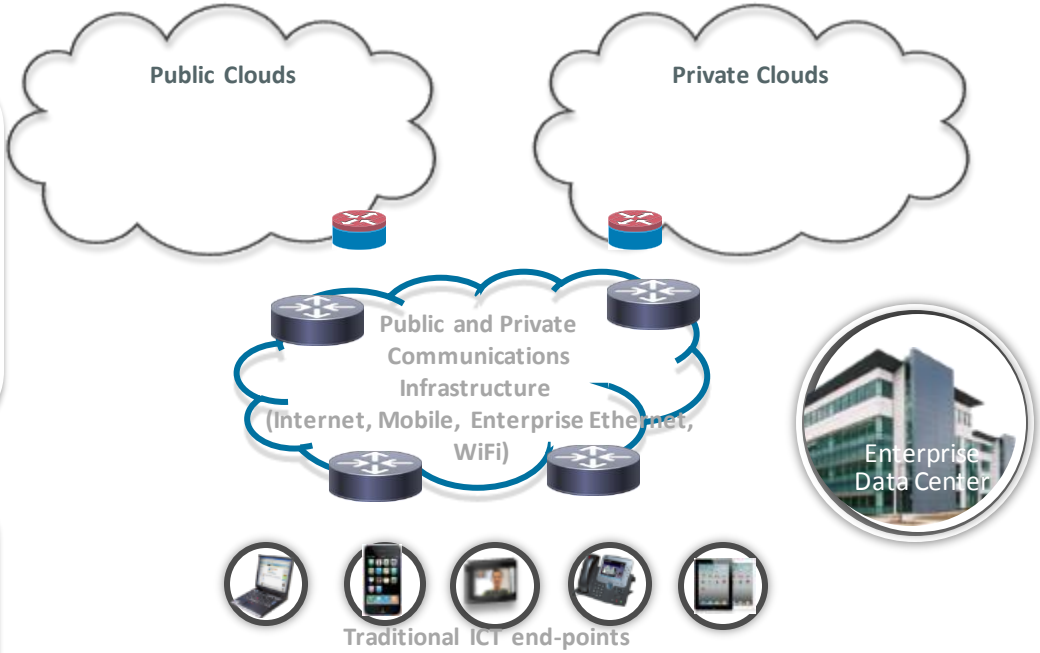
The Internet of Things: Information Technologies “Meet” Operational Technologies

Information Technologies Today:

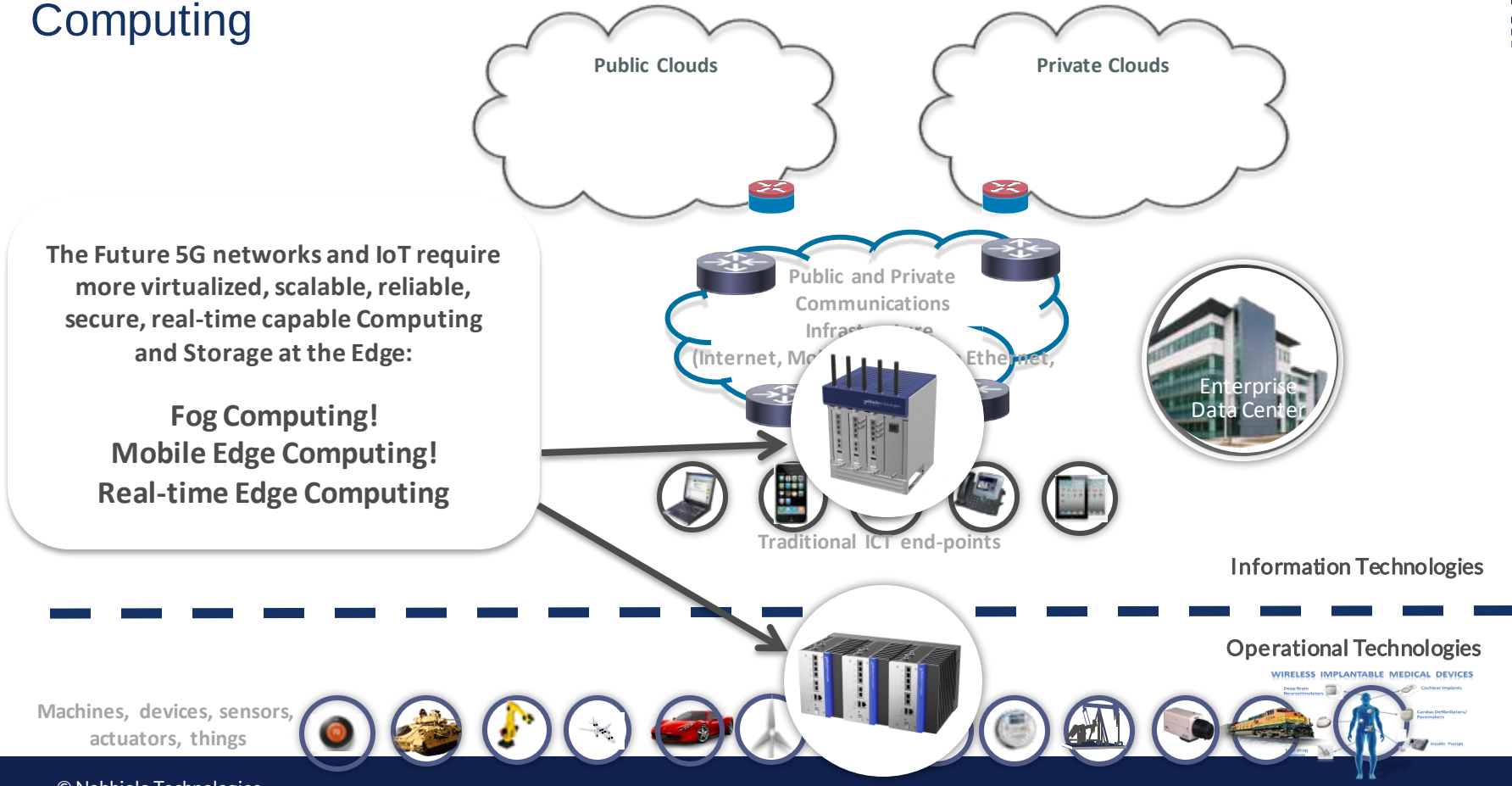
1. Clouds
2. Enterprise Datacenters
3. Traditional and Embedded Endpoints
4. Networking

The Internet of Things Brings Together Information Domain and Operations Domain through:

1. Connectivity
2. Data Sharing and Analysis
3. Technology Convergence

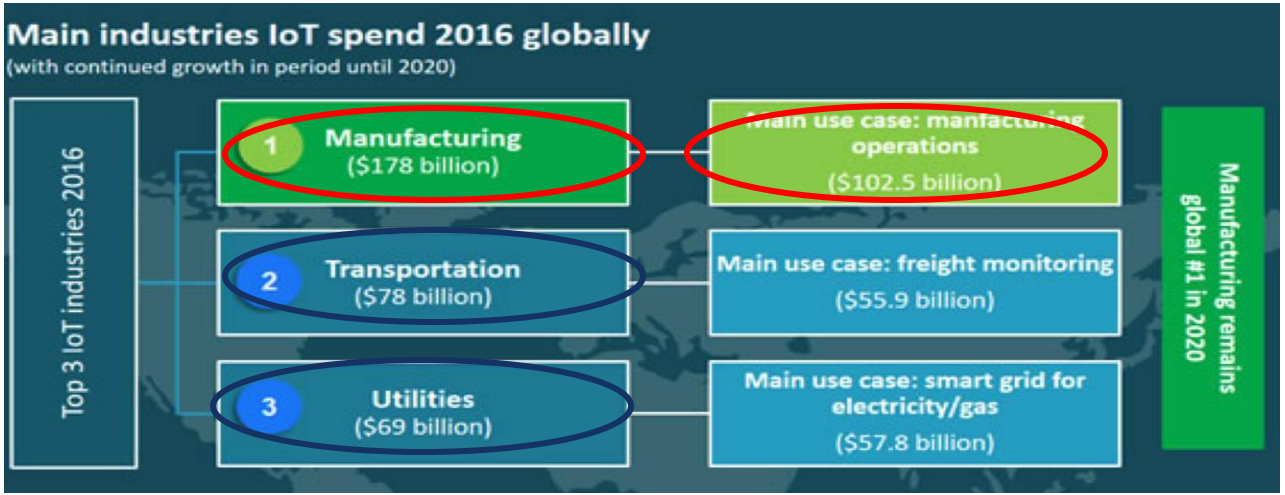


The Future 5G Network and Industrial IoT Both Require More Distributed Computing



Global Spend for Industrial IoT Relevant Industries: 2016-2020 Forecast

- Global IoT spending (CAGR) of 15.6% over the 2015-2020 forecast period, reaching $1.29 trillion in 2020
- Worldwide spending on the Internet of Things (IoT) is forecast to reach $737 billion in 2016
- In 2016 IoT spending led Industrial IoT verticals: Manufacturing ($178B), Intelligent Transportation ($78), and Utilities ($69B)



Source: IDC Report http://www.idc.com/getdoc.jsp?containerId=prUS42209117

The spending includes: hw, services, sw, and connectivity

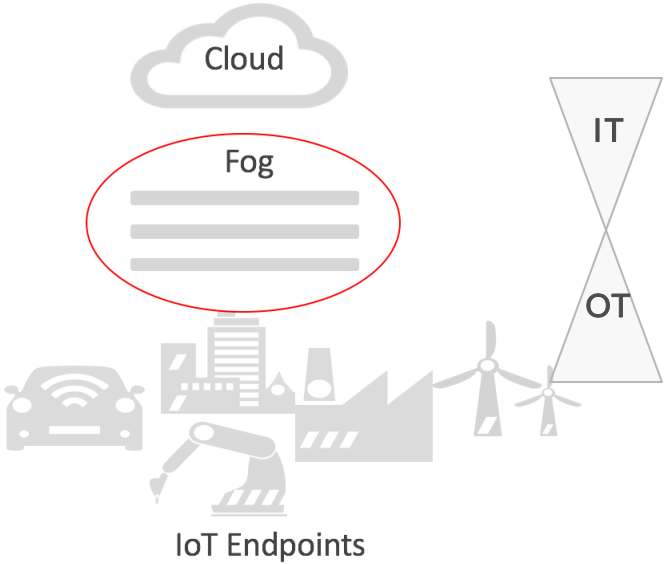
What is Fog Computing ?

The missing link between Clouds and Endpoints

Fog Computing brings:

Cloud-inspired computing, storage, and networking functions closer to the data-producing sources

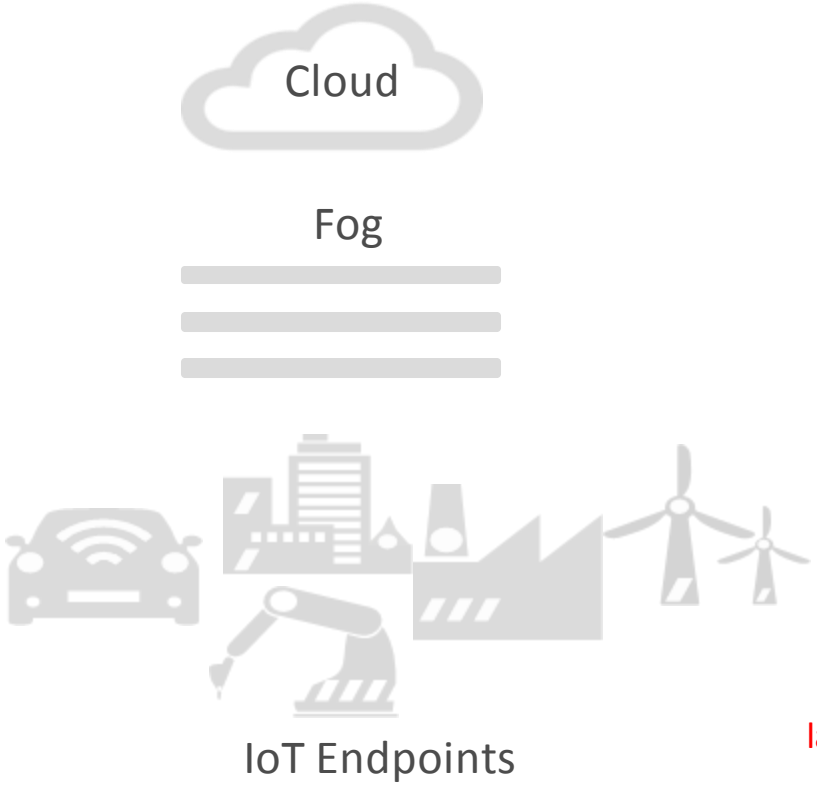
while integrating real-time and safety capabilities required in the OT domain



Fog Computing is the key enabler of a real **convergence** between IT and OT technology

Fog Computing: Motivations for a New Infrastructure Layer

By now Fog and its motivations are getting naturally accepted



1. Communications, gateway networking convergence
2. Edge data management, analytics
3. Distributed application hosting
4. Virtualization of all resources, multi-tenancy
5. Security and Privacy
6. Real-time, local control
7. Scalability
8. Reliability

OpenFog

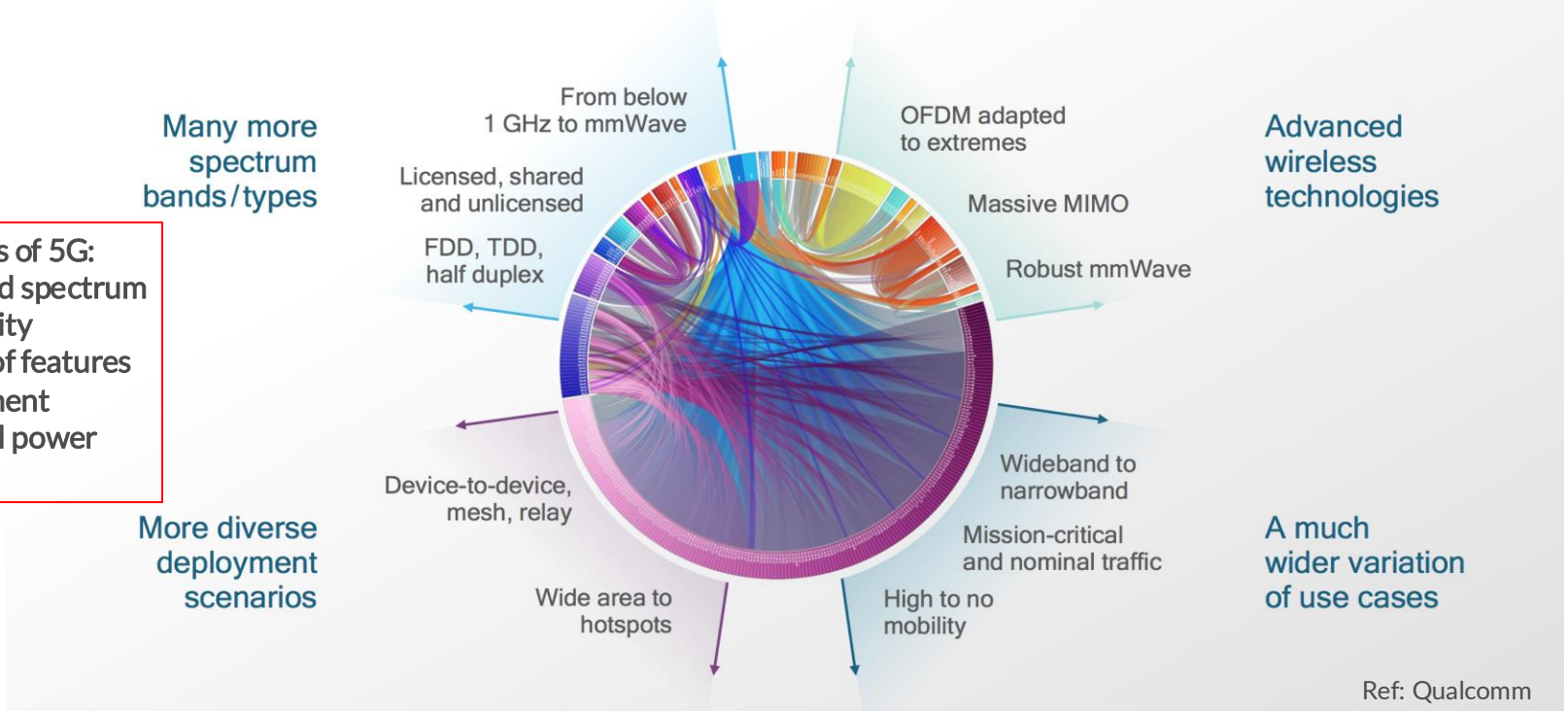
A Consortium with close to 100 Members Already!

Peter Levine (Andreesen&Horowitz) during Gartner keynote session last week: *"the cloud computing is dead, the intelligence/processing is going down close to the things"*

5G: Planning a Huge Role in the Support of Industrial IoT Applications

Adopting Important Bandwidth, Deterministic, Low Latency, Scale and Coverage Requirements (E.g., Massive IoT, Autonomous Vehicle Communications, High Reliability,…)

Key Values of 5G:
- Licensed spectrum
- Reliability
- Range of features
- Investment
- Political power

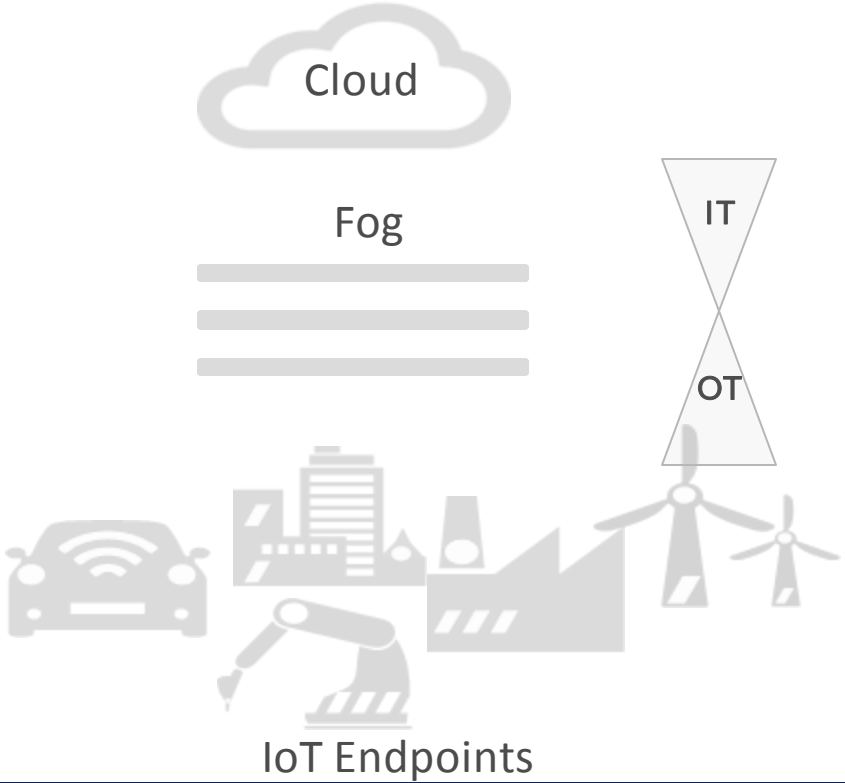


Ref: Qualcomm

Key Architectural Angles Characterizing the “Fog“ and Relevant to 5G :

IT to OT Convergence
Hierarchical Data Management and Analytics
Virtualized and Distributed Application Platform
The Evolution of Control
Decentralized Security

Fog Computing: Manifesting and Enabling the Convergence of IT and OT Technologies at the Edge



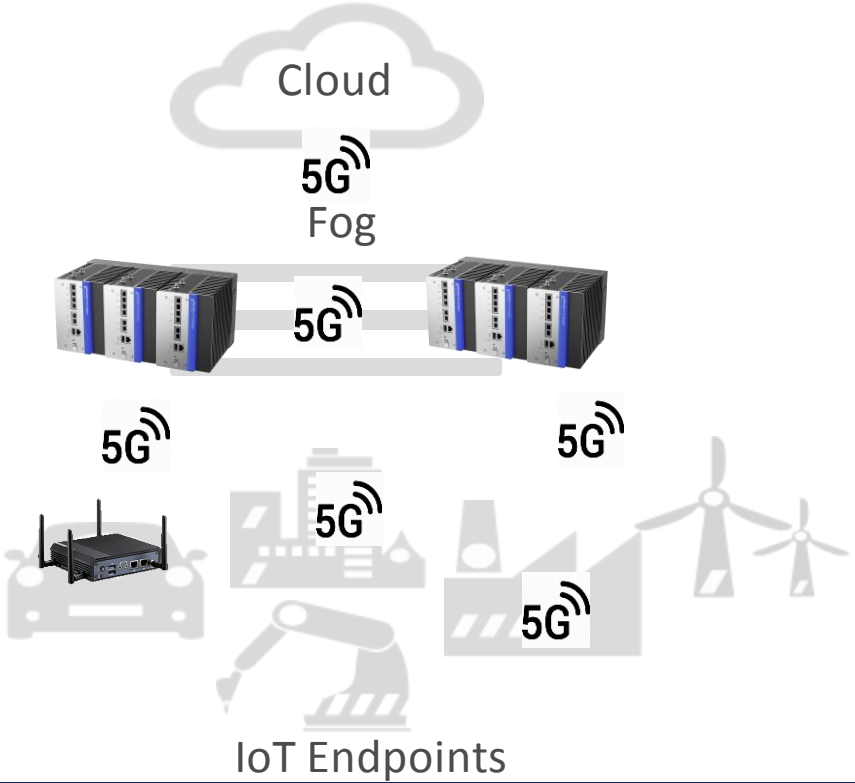
Information Technologies:

Virtualization and Multi-Tenancy, Software Management Automation, Data Analytics, Scalability, Software Defined Networking (SDN), Security and Privacy

Operations Technologies:

Real-time, Safety, Reliability, Control, Machine Connectivity and Data Acquisition, Human Machine Interface

Fog Computing: At the Convergence of IT and OT Networking Technologies – Multiple Future Roles for 5G



Information Networking Technologies:

Ethernet, WiFi, Cellular 3/4/5G, Bluetooth LE, SDN

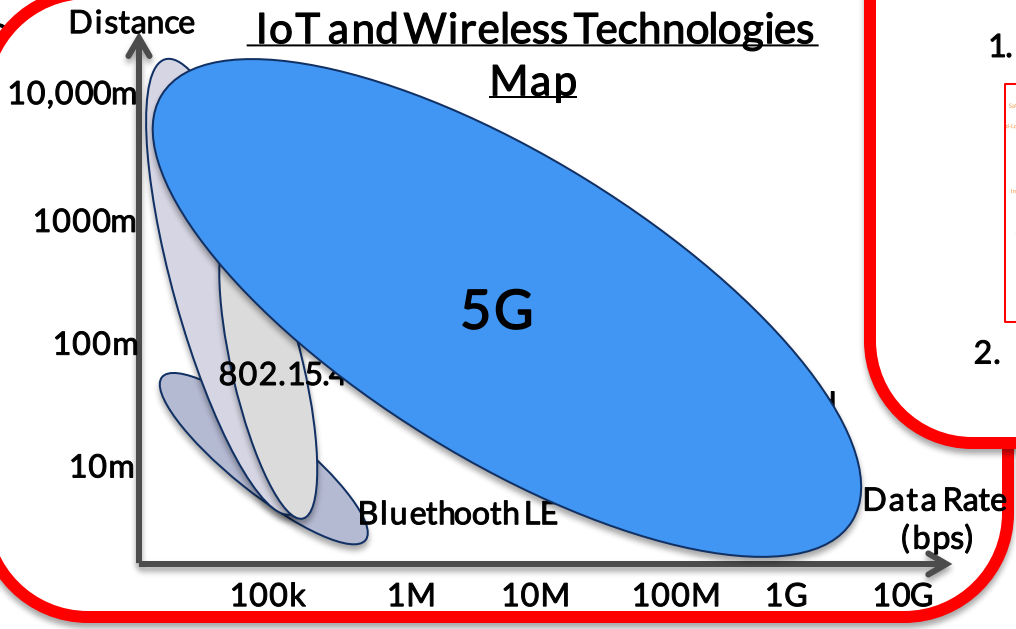
Operations Networking Technologies:

Real-time capable and Safety capable Field Networking Industrial Wireless, IEEE TSN (Deterministic Ethernet), LoRA, PLC

Fog Computing: At the Convergence of IT and OT Networking Technologies – Multiple Options Will Compete

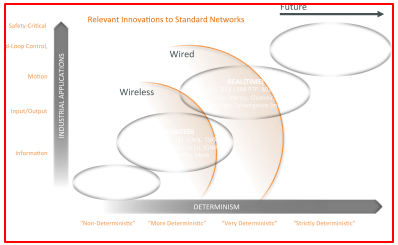
Wireless Technologies:

1. Cellular (2G/3G/4G
2. Bluetooth Low En
3. LoRa (Low power, bandwidth)
4. IEEE 802.15.4 wit
5. WiFi: Low Power, Vehicular (802.11



Wired Technologies:

1. Deterministic Ethernet

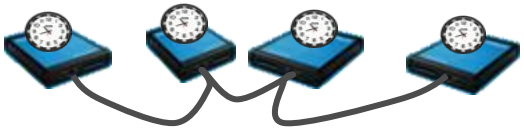


2. Power Line Communications

Fog Computing Needs Deterministic Networking: Deterministic Ethernet

"Time Triggered", and a Standard as IEEE Time Sensitive Networking (TSN)

Deterministic, Time-triggered Ethernet is based on:



1) A global notion of time

2) A communication global schedule (when to do what)

Fundamental for Industrial IoT!

Deterministic = Reliable, Very Low Jitter, even more than Low Latency

Future Standard for Automotive, Transportation, Industrial,…

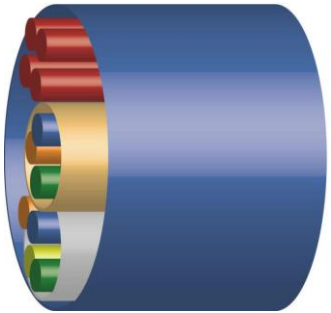
Network Virtualization based on Deterministic Ethernet

TTTech

Synchronous Traffic
- real-time control
- safety

Streaming
- audio
- video

Standard Ethernet Traffic
- diagnostics over IP
- download and updates



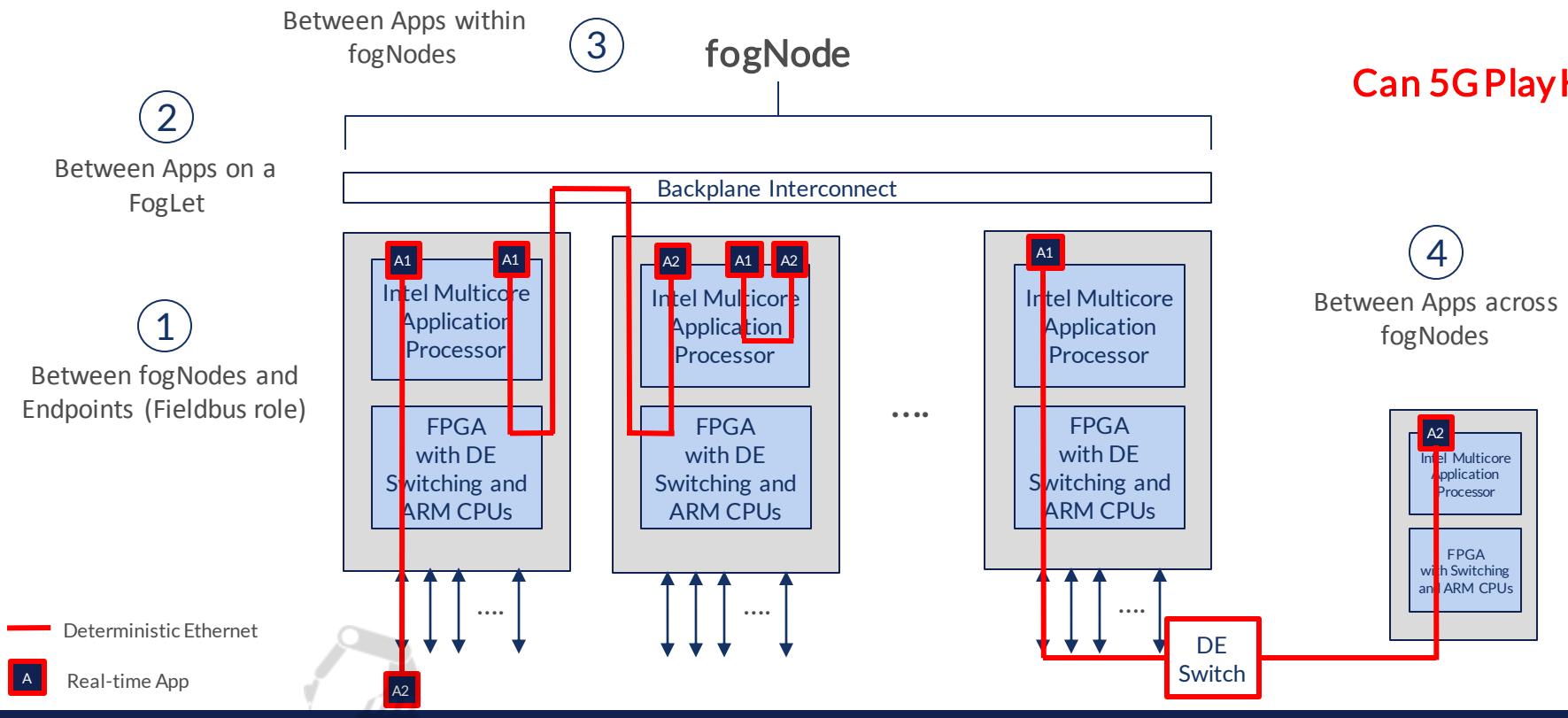
Many Virtual Links on a Single Cable

- Guaranteed timing for hundreds of real-time control functions
- Guaranteed bandwidth even in case of excessive network loads
- Guaranteed delivery even in case of network faults

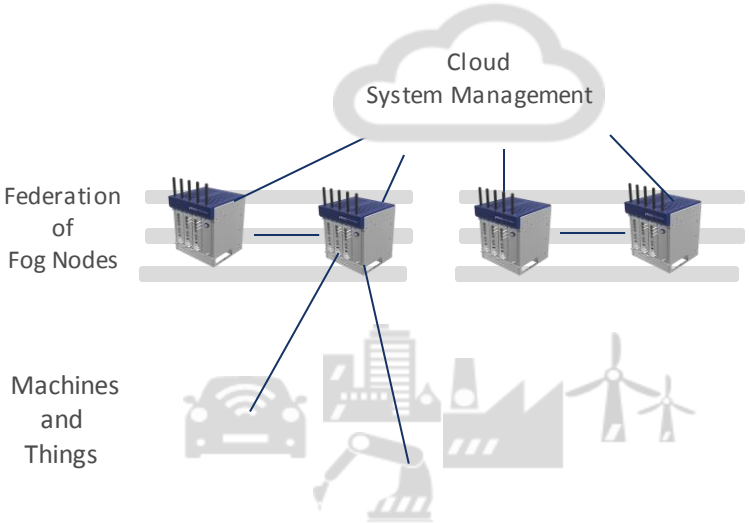
www.tttech.com

Real-Time Fog Computing Requires Deterministic Ethernet

Many Deterministic Communications Scenarios Across Distributed Real-time Applications

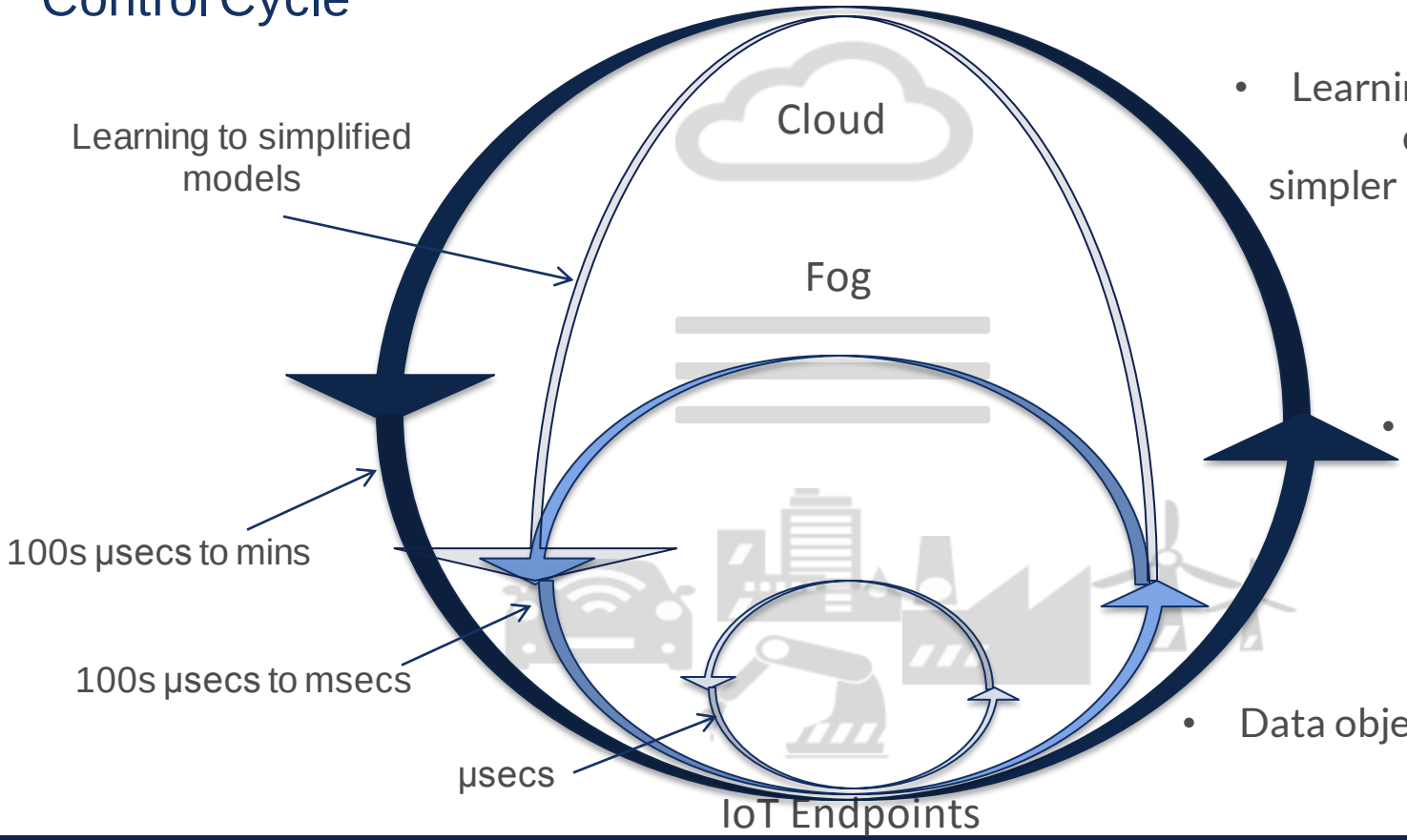


Fog Computing as a Distributed System: Remote or Local Management of a Distributed, Federated Collection of Nodes



- Zero-Touch deployment of Fog nodes, and assets
- Application hosting and full Life Cycle Management
- Asset Management
- Management and scheduling of real-time resources
- End-to-end security management
- Fog node federation, distributed storage

Fog Computing: Supporting a Hierarchical Data Acquisition-Analysis-Control Cycle

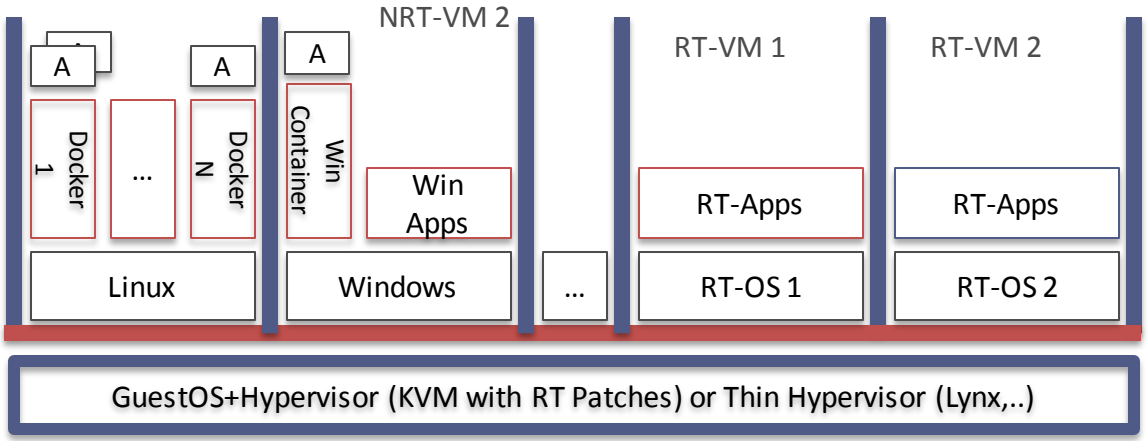


- Learning in the Cloud and deploying simpler models in the Fog
- Fast reaction to rich local analysis
- Data objectization and reduction

Fog Computing: Real-time Capable Virtualization to the Edge

Virtualization:

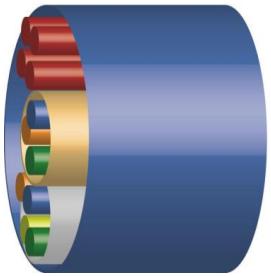
A combination of physical separation (multicore), hard, RT-NRT Virtual Board/Machine based virtualization and more lightweight Linux/Windows Container or Docker based virtualization

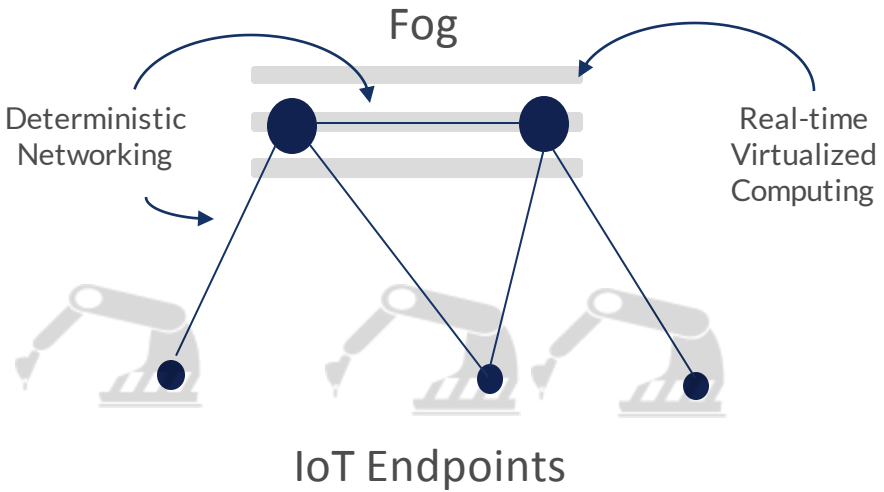


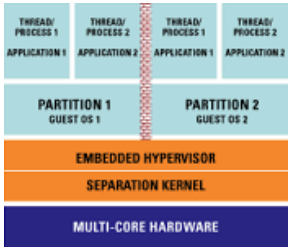
Fog Computing: Enabling the Convergence of Control

Deterministic Networking and Real-time Virtualized Computing enable the Convergence of Multiple Control Functions, one step removed from the controlled Endpoints:

The Software Defined Machines! (Ref: GE)

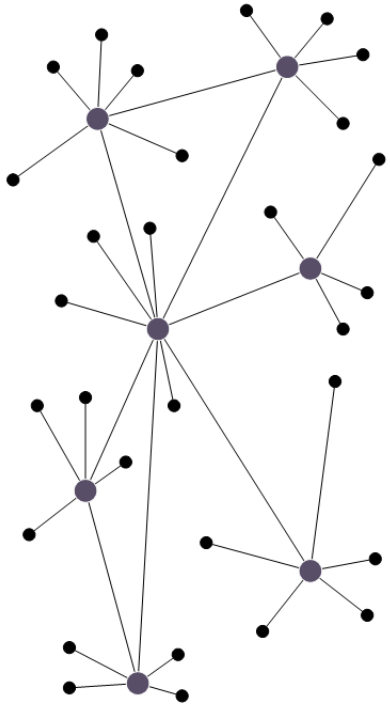




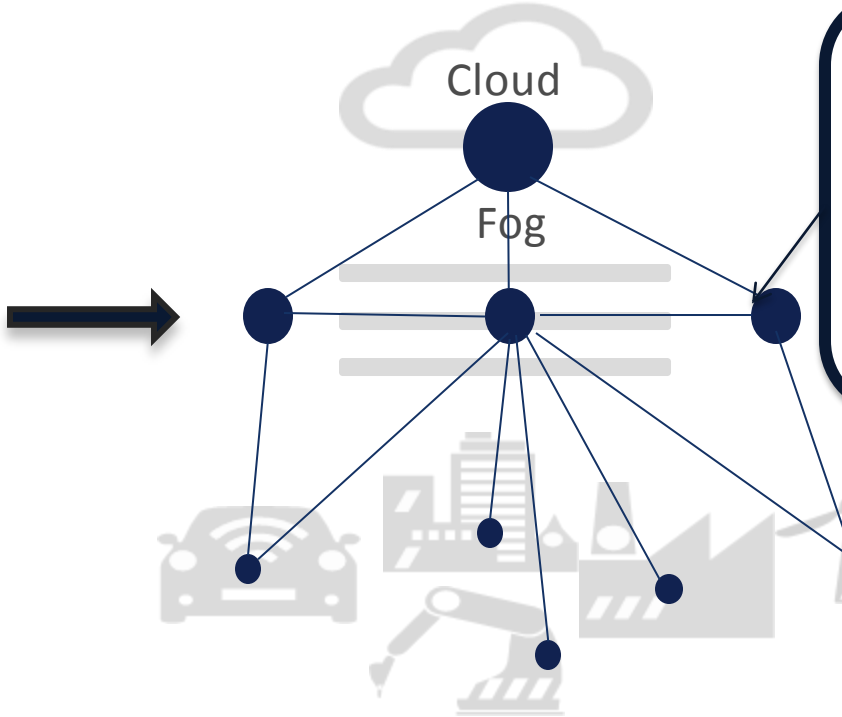


Fog Computing: Enabling Decentralized Security

Particularly Natural for Security in a Fog Based Infrastructure



Decentralized



Fog Resources Can Be Used to Help Less Capable Devices, i.e.,:

- **Identify**
- **Protect**
- **Isolate**
- **Verify**
- **Upgrade**

A Fundamental Mediation Role

Fog Computing and 5G, Natural Partners for the Future of Key Industrial IoT Verticals:

- Industrial Automation
- Automotive and Intelligent Transportation
- Smart Grid

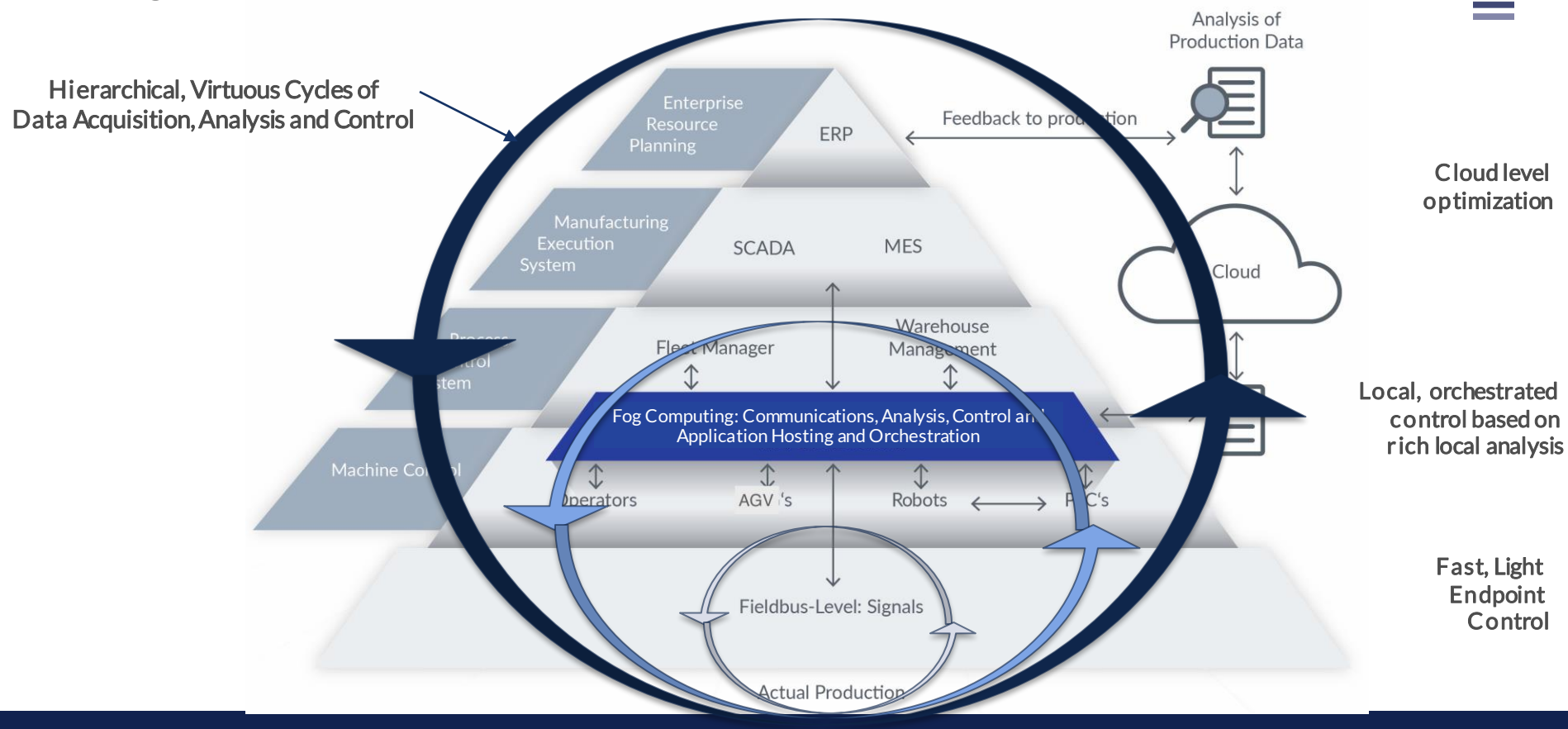
Motivations: Licensed spectrum, reliability, range of features, investment, ….

Industrial Automation

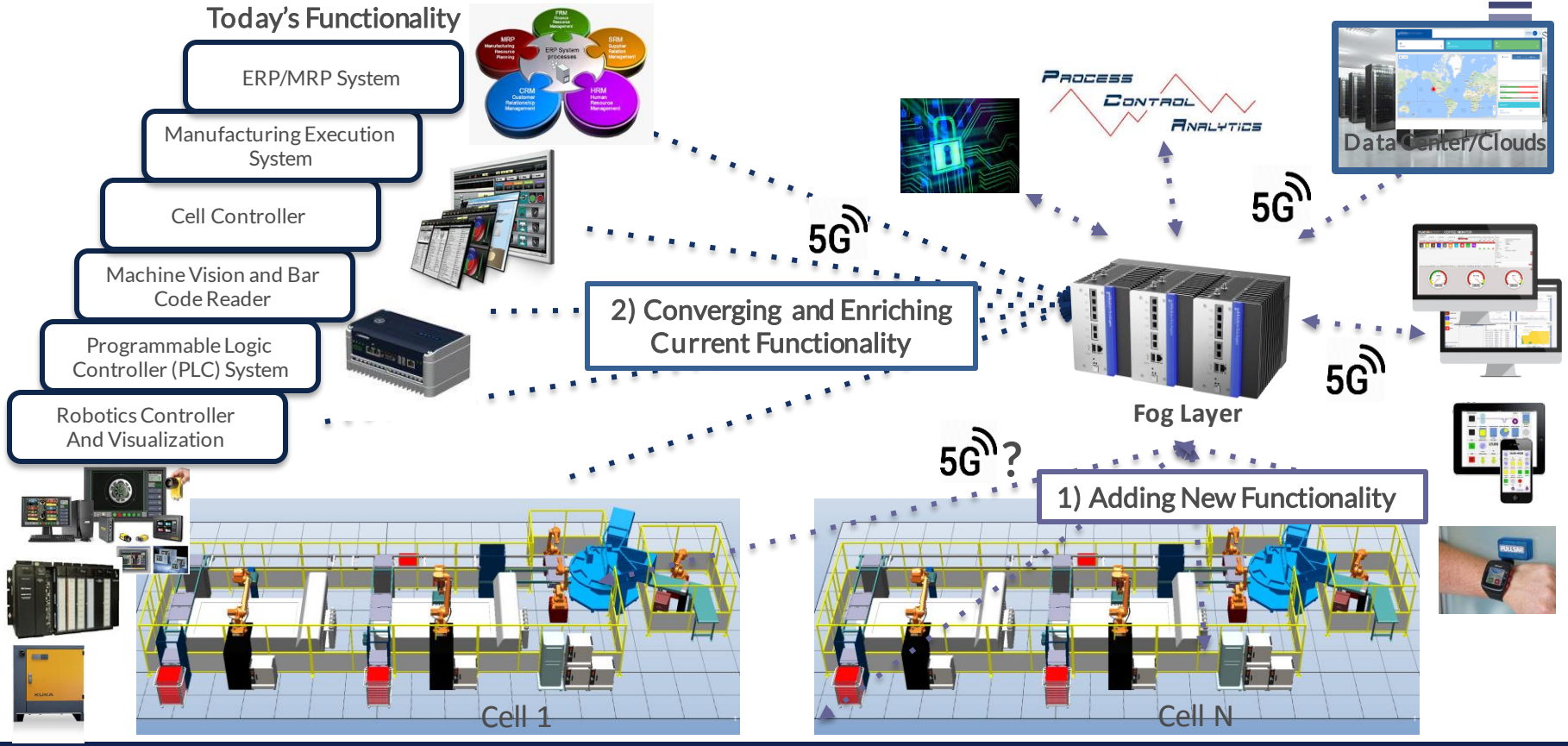
Starting from Automotive Body Shops and Precision Machine Floors

Fog Computing: A New Functional Layer in the Industrial Pyramid

Driving **IT to OT Convergence** & the **Future of Control** for Industrial IoT and Industry 4.0



Fog-Based Industrial Floor: Enabling New and Converged Functionality



Industrial Machine: A Complex System with Many Sensors, Actuators and Control Loops

Fog-Based Industrial Machine: Enabling New and Converged Functionality

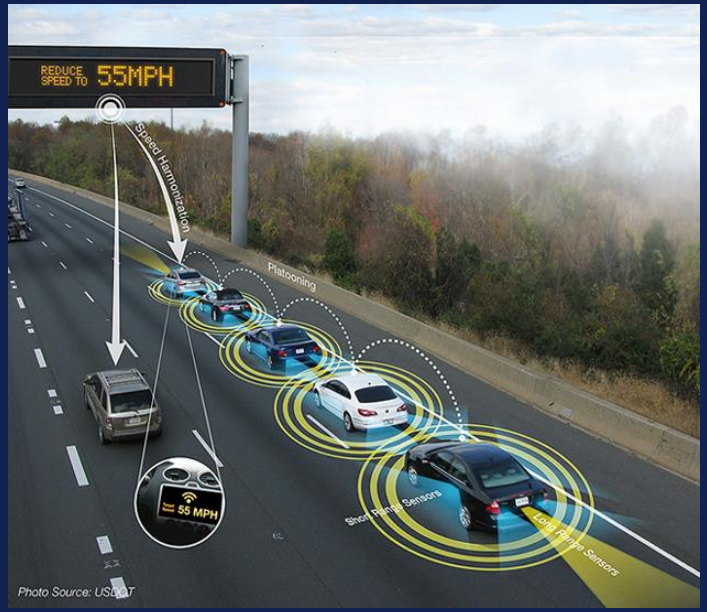
3G, 4G, and 5G: Manuy Use Cases in Industrial Automation

Use Case	Most Challenging Requirements	Value	Cellular Access Technology
Cell automation	Latency Reliability	0.5ms 99.9999999	5G (uMTC)
Automated guided vehicle	Mobility Reliability	10m/s 99.99999	LTE, 5G
Process Automation	Reliability	99.9999999	LTE, 5G, (mMTC, uMTC)
Logistics transportation tracking	Numb. devices Coverage	100000/sqkm Global	LTE
Components tracking	Numb. devices Mobility	1000000/sqkm Static	LTE
Remote assistance	Reliability	99.999%	5G (uMTC)
Augmented reality	Data rate	10Gbps	5G (xMBB)
Remote robot control	Reliability	99.999%	5G (uMTC)

Requirements and access technology for Industrial IoT use cases

Source: Ericsson Business Review, Issue 4

Automotive and Intelligent Transportation



The Role of Fog Computing in the Automobile Evolution

Key Directions:

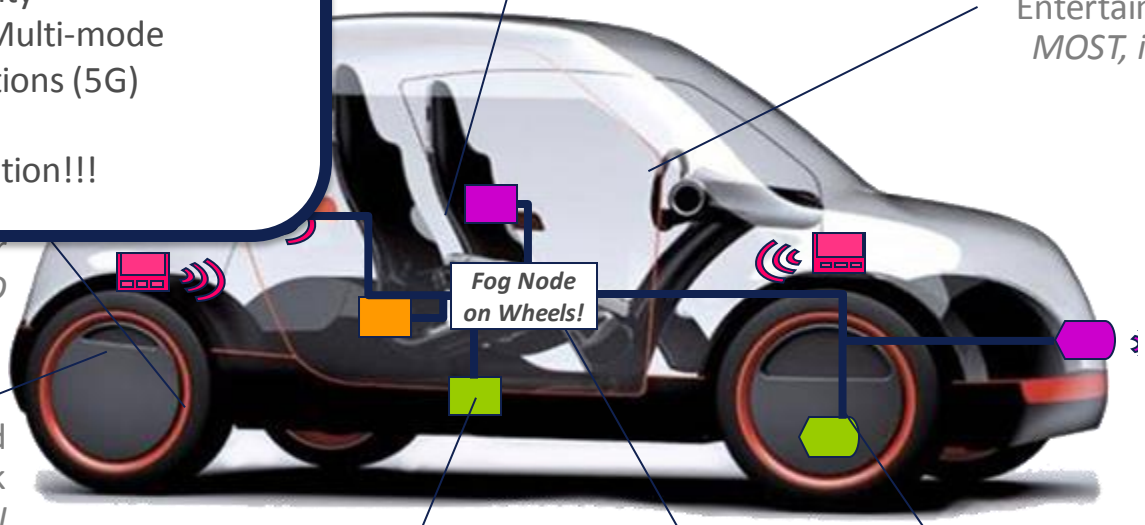
Internal Networking Convergence
Computing Virtualization
Security
Mobility and Multi-mode Communications (5G)

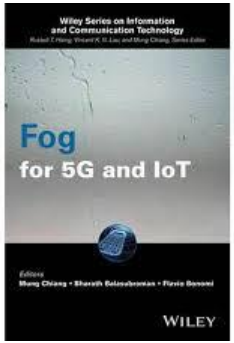
Centralization!!!

Deterministic Ethernet Network and Consolidated, Virtualized ECU "Data Center"

Entertainment network
MOST, internal WiFi

Bluetooth, Low Power WiFi, RFID





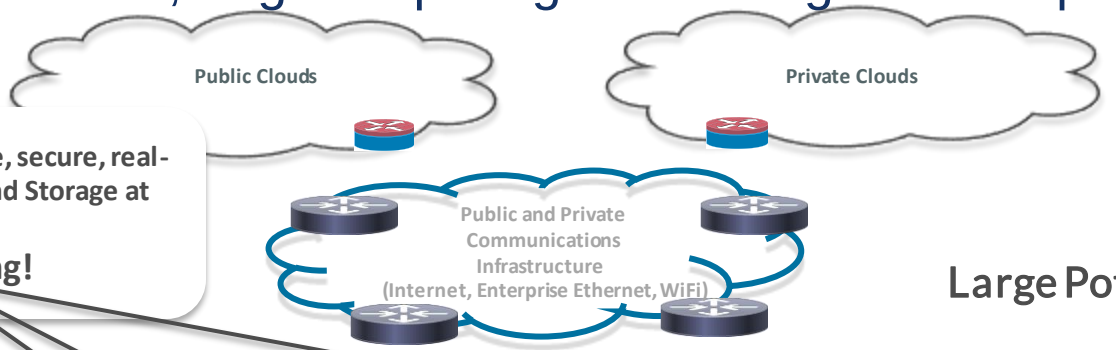
High-speed network
Hi-speed CAN

Electronic Control Unit (ECU)

Central Gateway

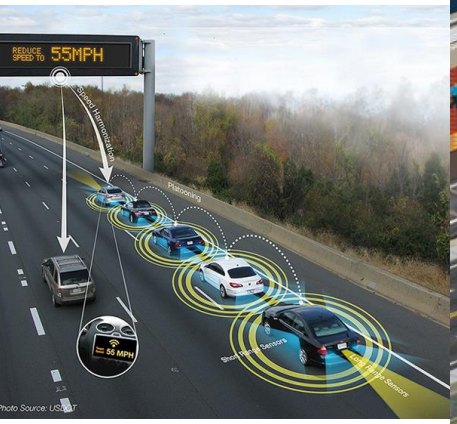
Wheel-Sensor

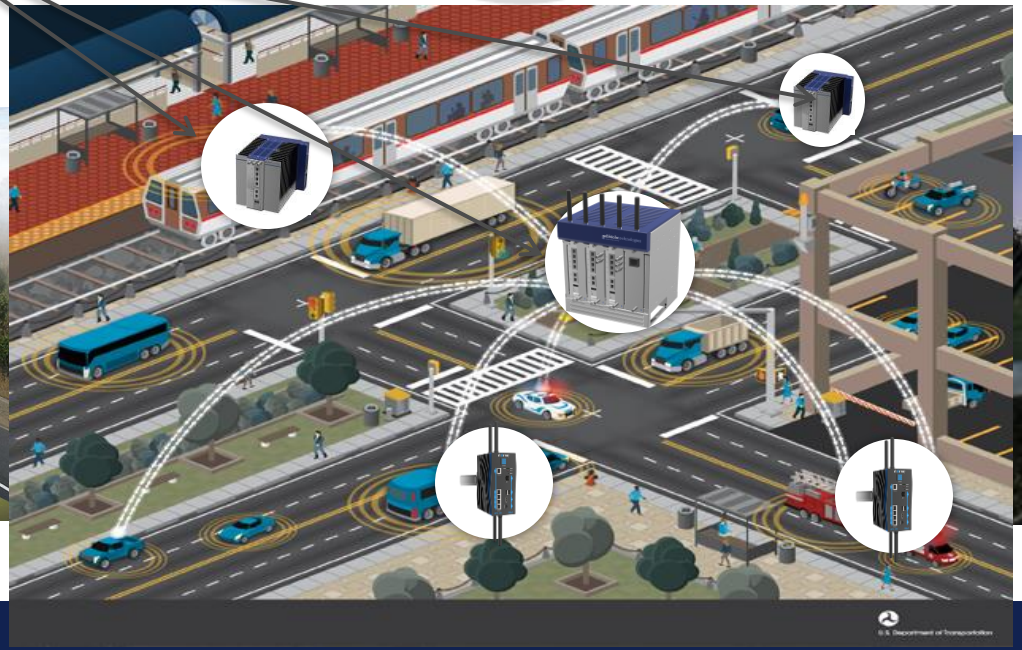
The IoT Infrastructure, Fog Computing and Intelligent Transportation



Virtualized, scalable, reliable, secure, real-time capable Computing and Storage at the Edge:
Fog Computing!

Large Potential Role for 5G!



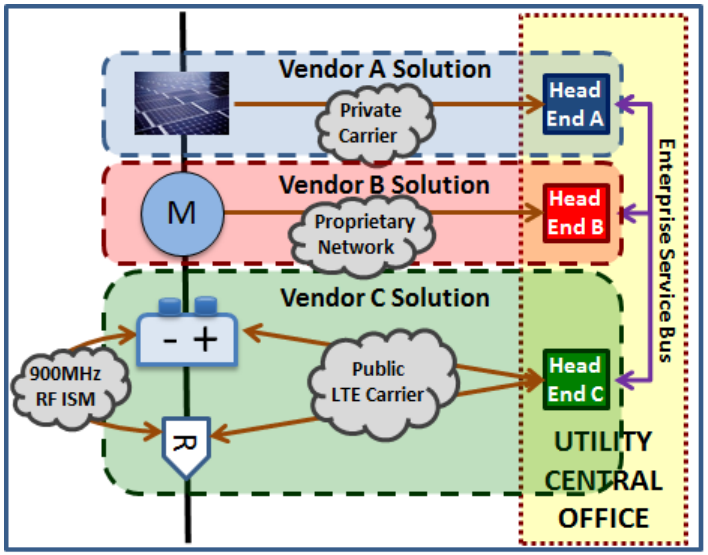


Smart Grid

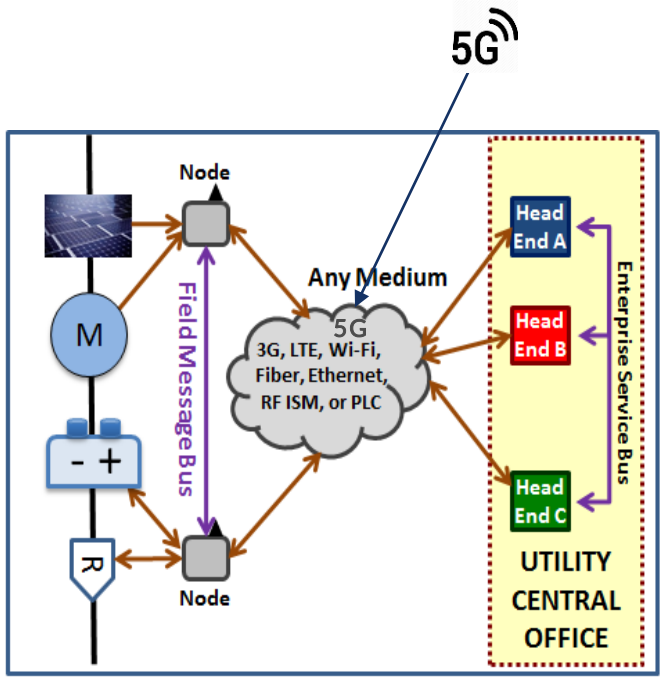
The Near Future of The Smart Electrical Grid Requires Fog Computing and 5G!

Distributed Intelligence, IT and OT Convergence, Standard, Interoperable, Secure

DUKE ENERGY



Current State: Message Bus at Data Center



Future State: Message Bus in Field and Data Center

The Near Future of The Smart Electrical Grid Requires Fog Computing and 5G!

Distributed Intelligence, IT and OT Convergence, Standard, Interoperable, Secure

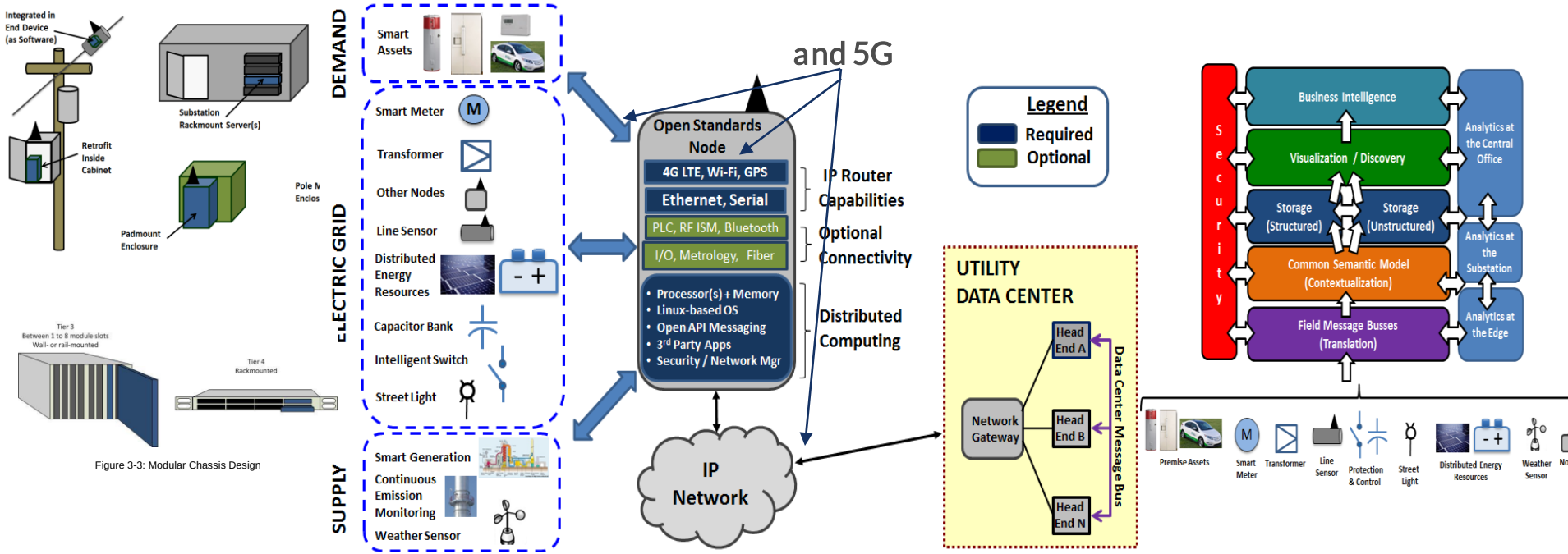


Figure 3-3: Modular Chassis Design

Figure 3-1: Duke Energy Distributed Intelligence Platform Node Architecture

The Near Future of The Smart Grid Requires Fog Computing and 5G!!

A Standardization Across USA Utilities, with Proof of Concept Deployment, has been Achieved in One Year !!!

RECOMMENDATION Approved by the RMQ Executive Committee
via Notational Ballot on February 4, 2016
For Quadrant: Retail Markets Quadrant

Requesters:	**RMQ OpenFMB Task Force**
Request No.:	**2015 Retail Annual Plan Item 9.a/R14008**
Request Title:	**Develop model business practices to support OpenFMB architecture for interoperable data exchange between distributed power systems devices on the electric grid's field area networks.**

Brief Introduction to Nebbiolo Technologies

Nebbiolo = Grape Enjoying the Morning Fog (=Nebbia) in Northern Italy

Producing wonderful wines: Barolo, Barbaresco,
Nebbiolo, Valtellina Reds

nebbiolotechnologies

pioneers of fog computing

Nebbiolo Technologies

Nebbiolo Technologies is architecting and building an innovative Fog Computing Platform for IoT Solutions

and applying it, first, in the vertical of Industrial Automation

Team: World-class, Cisco sourced, experienced (20+ people) team surrounded by a rich ecosystem of IoT technology partners

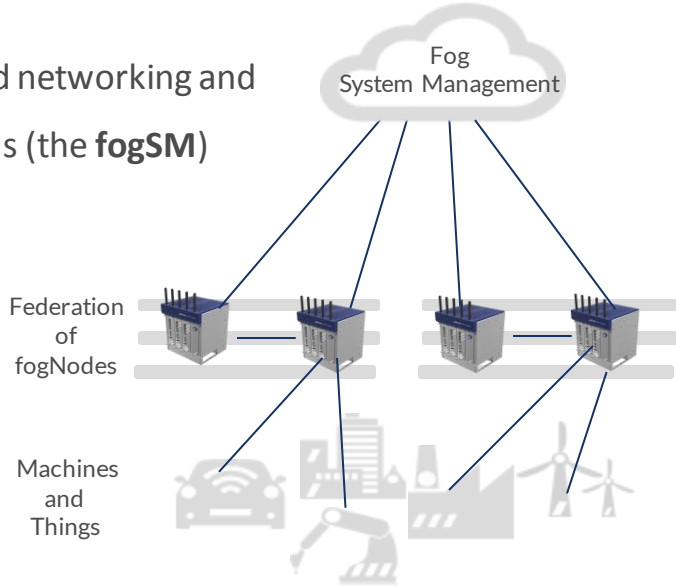
Investors: KUKA Robotics, TTTech and GiTV (Tokyo, Japan VC)

Milestones: 7 Patents pending; Strong Traction; Production deployments and PoCs ongoing; First product released (December 2016)

Nebbiolo Technologies Fog Computing Platform Components

1. A **flexible hardware architecture** manifesting in a family of **fogNodes**
2. A rich **software distributed stack** (the **fogOS**), enabling fast, secure, flexible communications, data management and application deployment
3. An **end-to-end system management** of distributed networking and computing systems, assets, software and applications (the **fogSM**)

Manageability	Secure Stack	Business Application
		IoT Infrastructure
		Application hosting & Orchestration
		Midddleware
		Cloud Infrastructure
	Secure boot	Fog Infrastructure
		Admin Plane
		RTOS/Kernel
		Host OS/Hypervisor
		Hardware (X86/Arm)



Conclusions

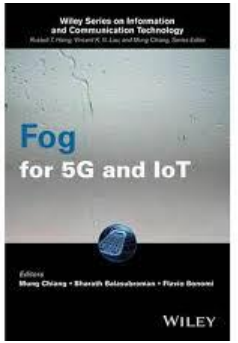
Conclusions

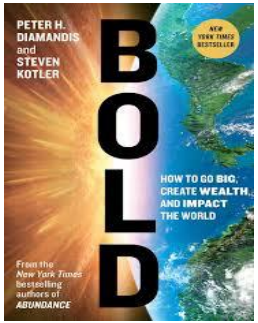
Fog Computing and 5G are Natural Partners for the Future of Industrial IoT

More Reliable, Lower Latency, Deterministic Wireless Networking is Essential for Real-time Fog Computing and its Industrial Applications!

More Collaboration nad Experimentation is Required!

Let us Move Boldly, Together: The Future is Bright!





nebbiolotechnologies

fog computing pioneers

THANK YOU,
AND REMEMBER ..

Nebbiolo Technologies, Inc.
860 Hillview Court, Suite 310
Milpitas, CA 95035
P +1 (408) 770-2828