INDUSTRIAL AUTOMATION AT INTEL

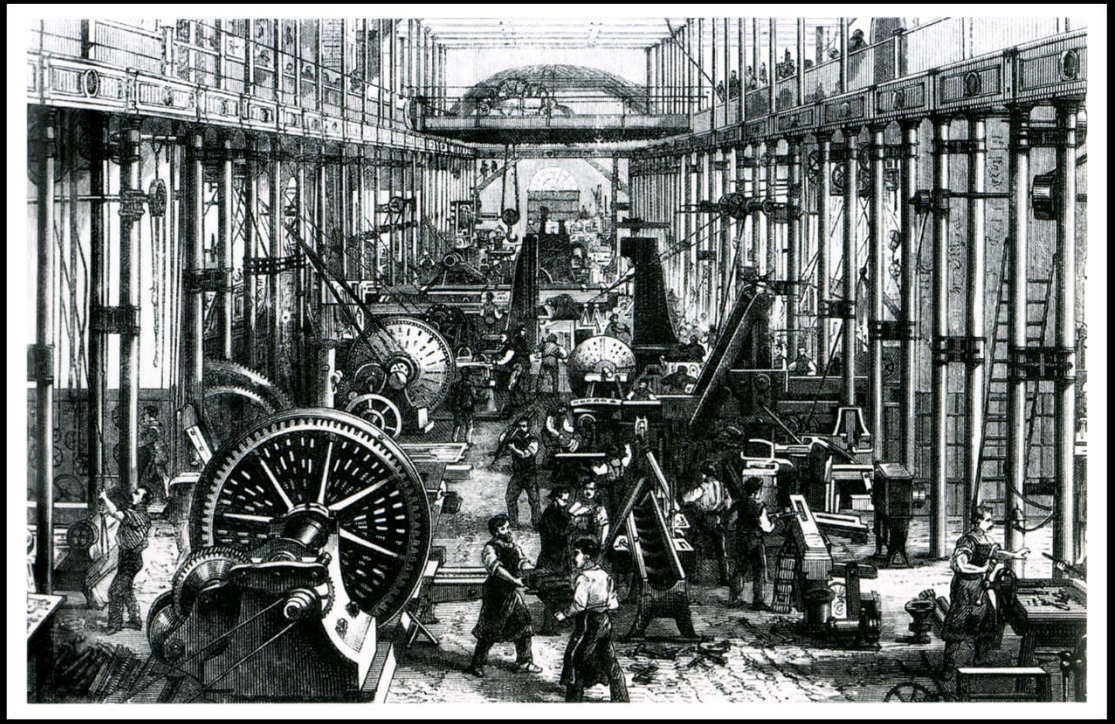
Core and Visual Computing Group, Intel®

BENEFITS OF AUTOMATION

- Increased Yields
- Improved Yield Quality
- Reduced Machine Down Time
- Improved Safety
- Increased Operational Flexibility

1980S

- No Robotic Material Transport
- ”Run Cards” on wafer boxes
- Basic Equipment Standards
- Basic Equipment Control
- Basic Manufacturing Execution System



1990S

- Early Robotic Transport
- Automated Statistical Controls
- Improved Automation Standards
- Improved Equipment Control
- Improved Manufacturing Execution Systems
- Automated Decision Making

TODAY

- Pervasive Robotic Transport
- Advanced Process Controls
- Real-Time Excursion
- Advanced Manufacturing Execution Systems
- Advanced Decision Making
- Predicative Maintenance
- Big Data Repository
- SEMI Standards

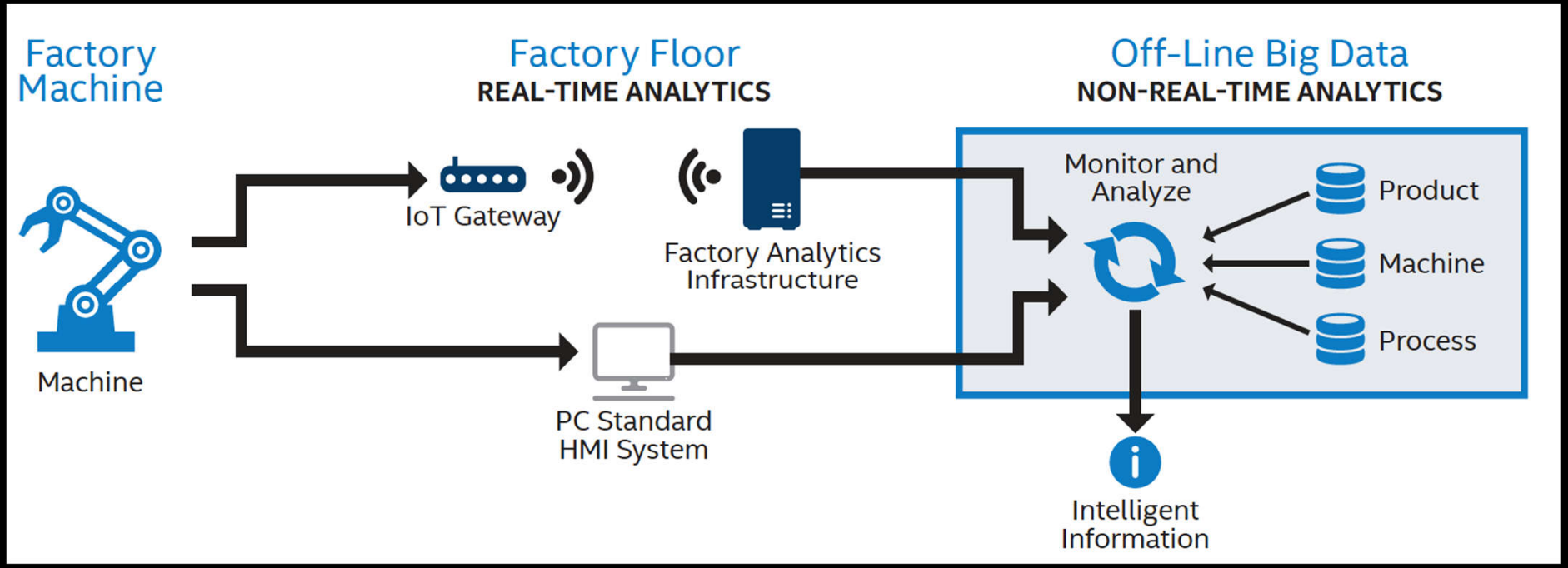
STANDARDS

- Standard HMI and Software Interfaces
- Semiconductor Equipment Communications Standard / Generic Equipment Model (SECS/GEM) protocol for all material handling
- Standardized Data Format
- Tool interoperability across vendors

DATA

- Current State: Real-Time Process control, alerts, anomalies
- Historical State: Previous yields, sensor data, errors
- Future State: Predictive maintenance, process optimization, quality improvement

INTEL FACTORY FLOOR



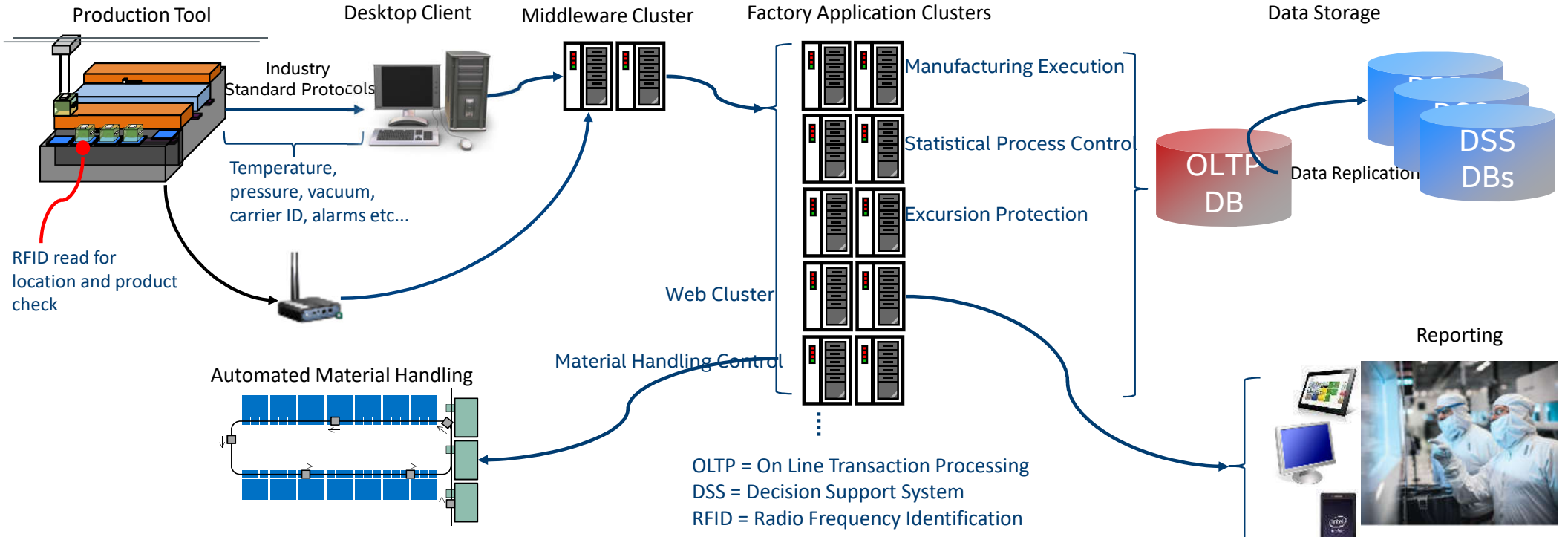
INTEL'S IOT FAB: HIGHLY INSTRUMENTED & HIGHLY CONNECTED

Real-Time Process Control
Responsive factory = higher quality

Optimized Factory Flow
Aligned with supply chain needs

Predictive Maintenance
Optimizing equipment utilization

Pervasive Robotics and Tool Control
Accelerating production speed



INTEL'S FULLY AUTOMATED AND OPTIMIZED FACTORIES ANALYZE OVER 1 PB OF DATA A DAY

Data Collection	Data Aggregation & Actions	Data Scoring, Analytics & Model Updates	Business Intelligence Result Sharing

Factory Floor

- 2,000+ thick clients (all Intel® x86 64-bit desktop platforms)
- 1,000-2,000 production semiconductor tools
- 200,000+ feet of Ethernet cable
- 100+ access switches and WAP

Automated Materials Handling System

- Robotic delivery and storage systems
- 150+ high speed interbay robotic delivery vehicles
- Covers 400k sq ft of cleanroom space
- 5+ miles of vehicle track on the ceiling; 200+ overhead robotic delivery vehicles
- 200+ high-intensity power distribution panels

Data Center

- 600+ servers (all Intel x86 64-bit)
- 200+ routers, switches, firewalls
- >1PB of centralized storage
- MS Windows* and Linux* OS
- 150,000+ feet of fiber
- 200+ routers, switches, firewalls

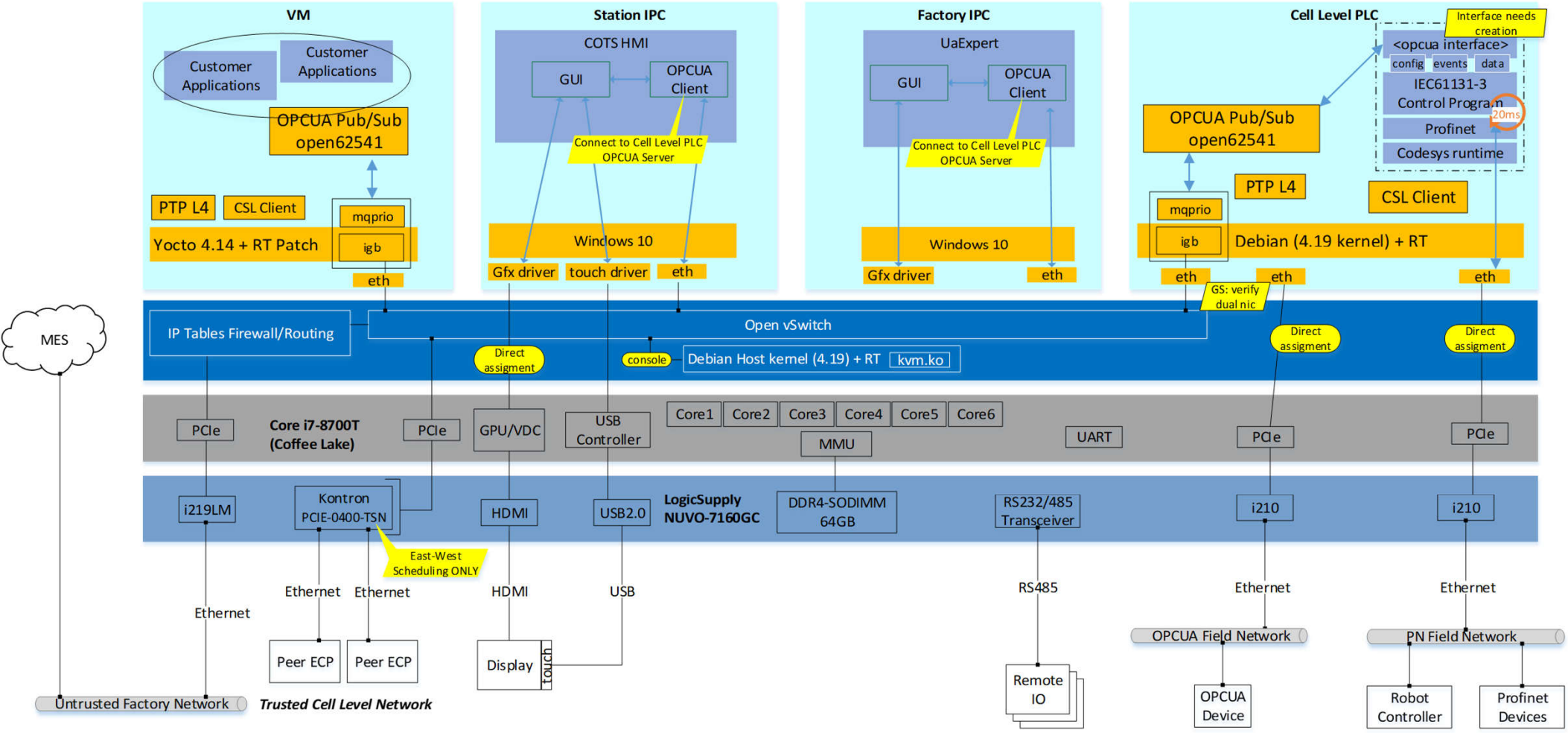
Security End to End

*Other names and brands may be claimed as the property of others.

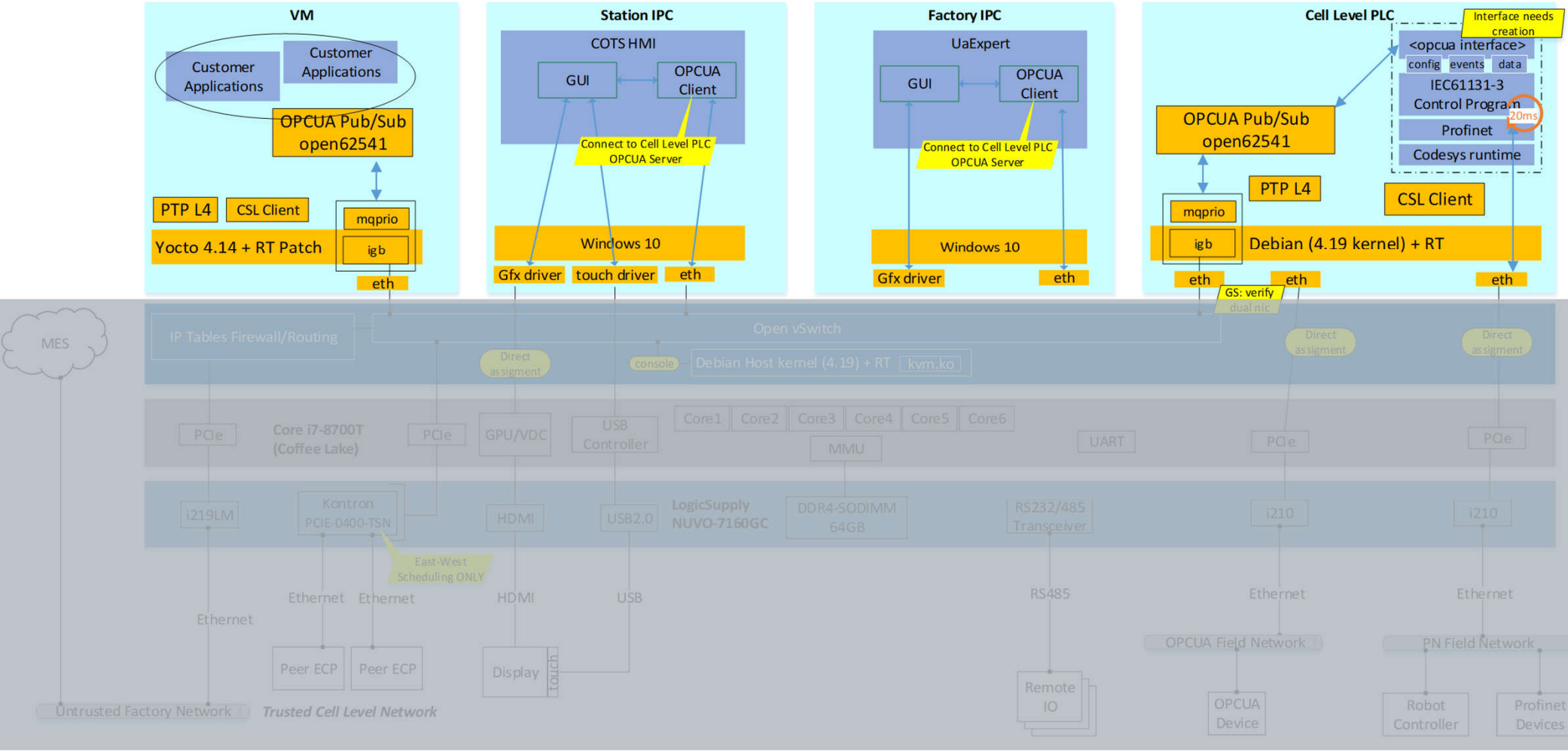
Lessons learned

- Raw IOT data on it own is next to useless … context creates value.
- Management of data volumes is crucial. Systems are easily overwhelmed by IOT data volumes
- Smart data association improves performance dramatically.
- End to End solutions offer productivity and efficiency benefits that allow engineers to exploit data in ways that are not possible with traditional data warehousing approaches.
- Almost every IOT data source is uniquely structured. Transformation into a standardised form allows handling of the variety of IOT sources available.
- Service Orientated Architecture (SOA) design is well aligned to IOT environments as it is based on the exchange of data structures in a loosely coupled manner.
- Machine learning has achieved accurate predictions using for critical Fab parameters.
- The next challenge: AI technically possible but psychologically difficult as it requires release of control.

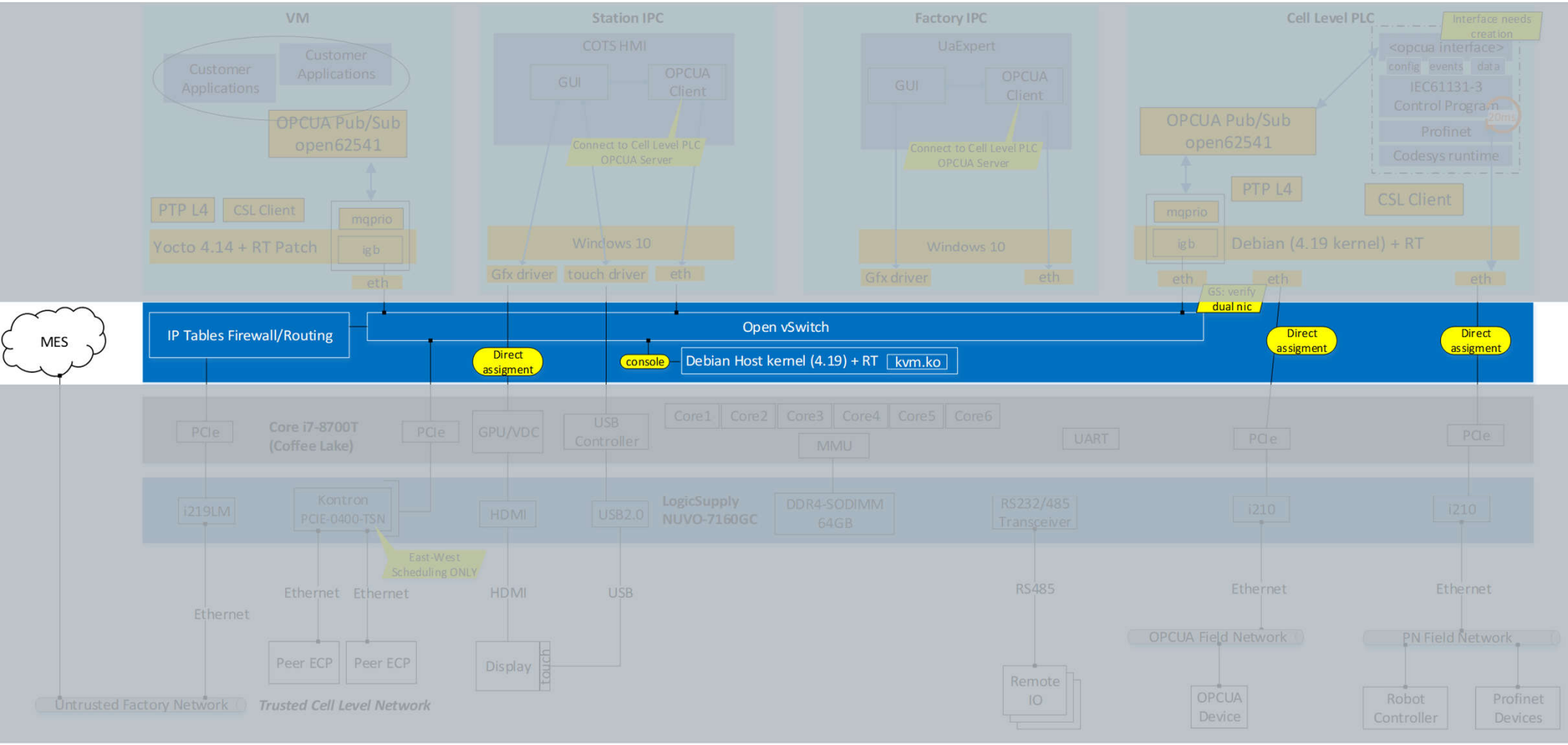
Intel Auto Manufacturing



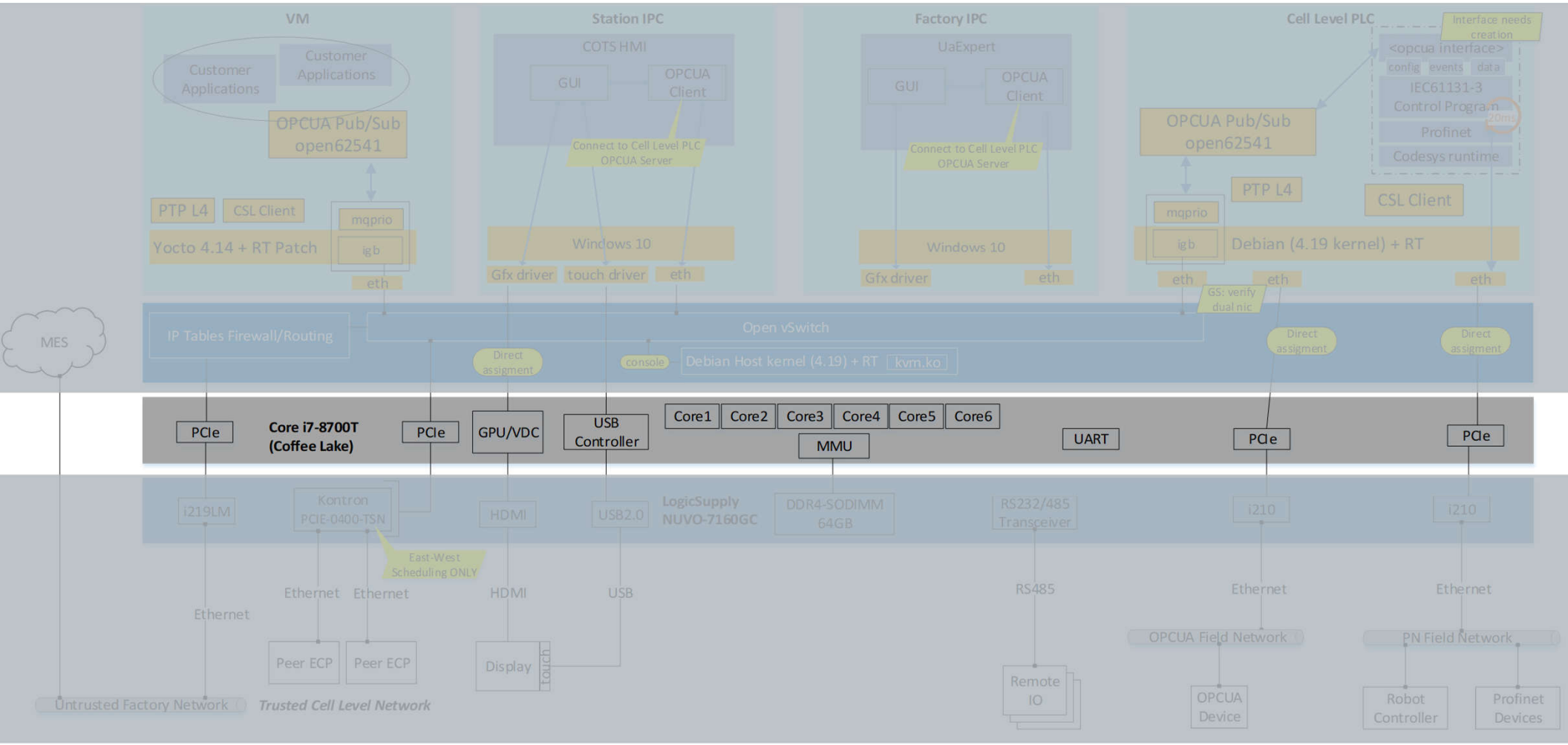
OS/Application Layer



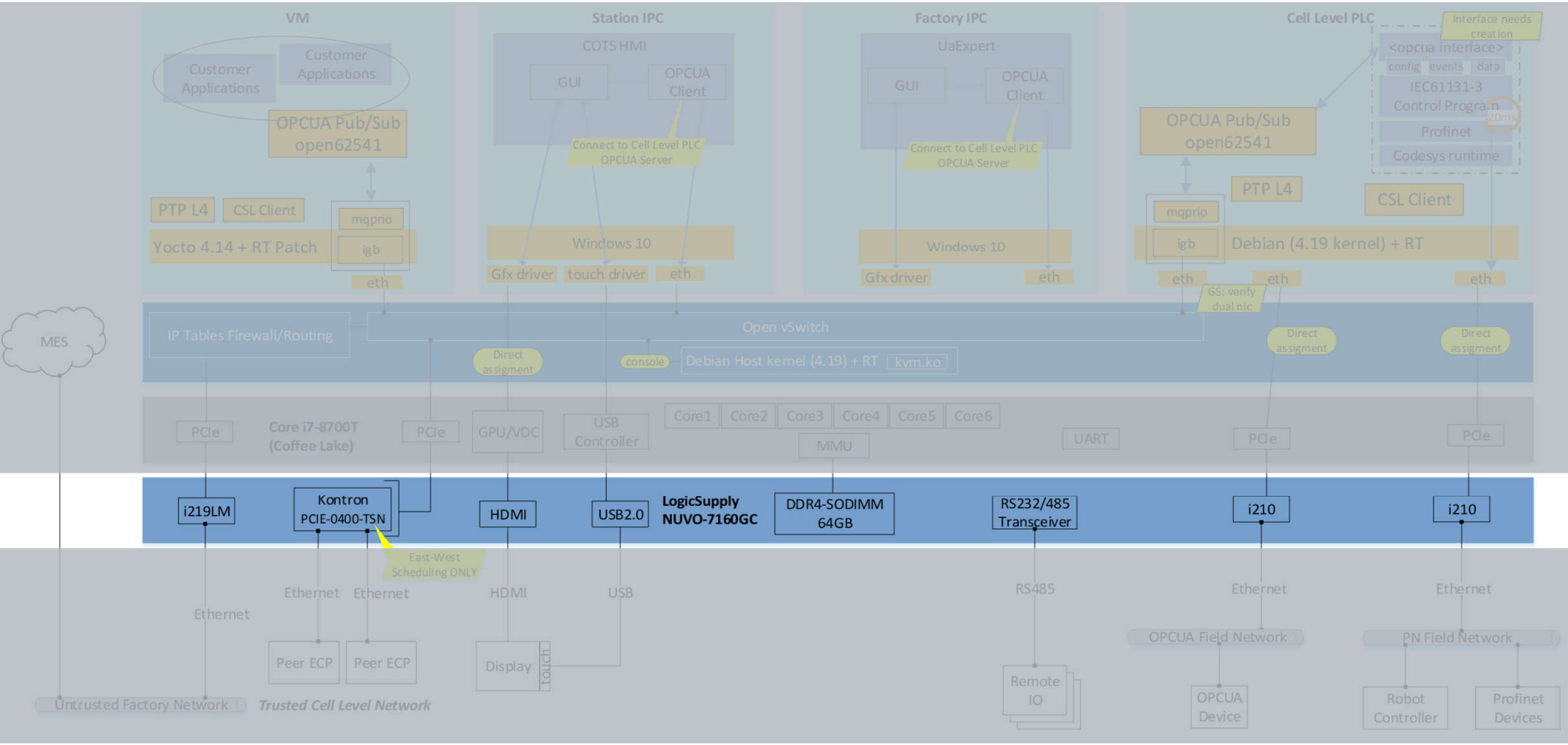
Hypervisor Layer



CPU Layer


VM
Customer Applications
Customer Applications
OPCUA Pub/Sub open62541
PTP L4
CSL Client
mqprio
igb
Yocto 4.14 + RT Patch
eth
Station IPC
COTS HMI
GUI
OPCUA Client
Connect to Cell Level PLC OPCUA Server
Windows 10
Gfx driver
touch driver
eth
Factory IPC
UaExpert
GUI
OPCUA Client
Connect to Cell Level PLC OPCUA Server
Windows 10
Gfx driver
eth
Cell Level PLC
Interface needs creation
<opcua interface>
config
events
data
IEC61131-3 Control Program
20ms
Profinet
Codesys runtime
OPCUA Pub/Sub open62541
PTP L4
CSL Client
mqprio
igb
Debian (4.19 kernel) + RT
eth
eth
eth
GS: verify dual nic
MES
IP Tables Firewall/Routing
Open vSwitch
Direct assigment
console
Debian Host kernel (4.19) + RT
kvm.ko
Direct assigment
Direct assigment
PCIe
Core i7-8700T (Coffee Lake)
PCIe
GPU/VDC
USB Controller
Core1
Core2
Core3
Core4
Core5
Core6
MMU
UART
PCIe
PCIe
i219LM
Kontron PCIE-0400-TSN
HDMI
USB2.0
LogicSupply NUVO-7160GC
DDR4-SODIMM 64GB
RS232/485 Transceiver
i210
i210
East-West Scheduling ONLY
Ethernet
Ethernet
Ethernet
HDMI
USB
RS485
Ethernet
Ethernet
Peer ECP
Peer ECP
Display
touch
Remote IO
OPCUA Field Network
PN Field Network
OPCUA Device
Robot Controller
Profinet Devices
Untrusted Factory Network
Trusted Cell Level Network

Peripheral Layer



Device/IO Layer