The Evolving Edge Connectivity in Industry 4.0 and the Role of Memory

Memory Solutions for the Industrial IoT and the Edge

October 2020

1   Micron Confidential

Hype Ideas That Became Transformational (not just the iPhone!)

Pokémon Go ca. 2016

Augmented reality in Enterprise
AR/VR headsets at Home
Hyper-personalization in Retail

Netflix ca. 1998

On-demand content
Subscription "As-a-Service" model
Mass-Streaming of data

Industry 4.0 ca. 2011

Cyber Physical Systems
IT/OT Convergence
Digital Twin
Industrial Edge

Big Machines, Big Data.

A societal shift in connectivity and compute

There will be estimated **41 Billion IoT** devices by 2027[1]

Video Analytics market is anticipated to reach over **$25.4 Billion** by 2026[4]

Edge compute market is estimated at **$28.8B**[5] by 2025

IoT security market estimated at $35B by 2023 @ **33.7% CAGR**[2]

By 2023, **70% of Automobiles** is anticipated to be **connected to the Internet**[3]
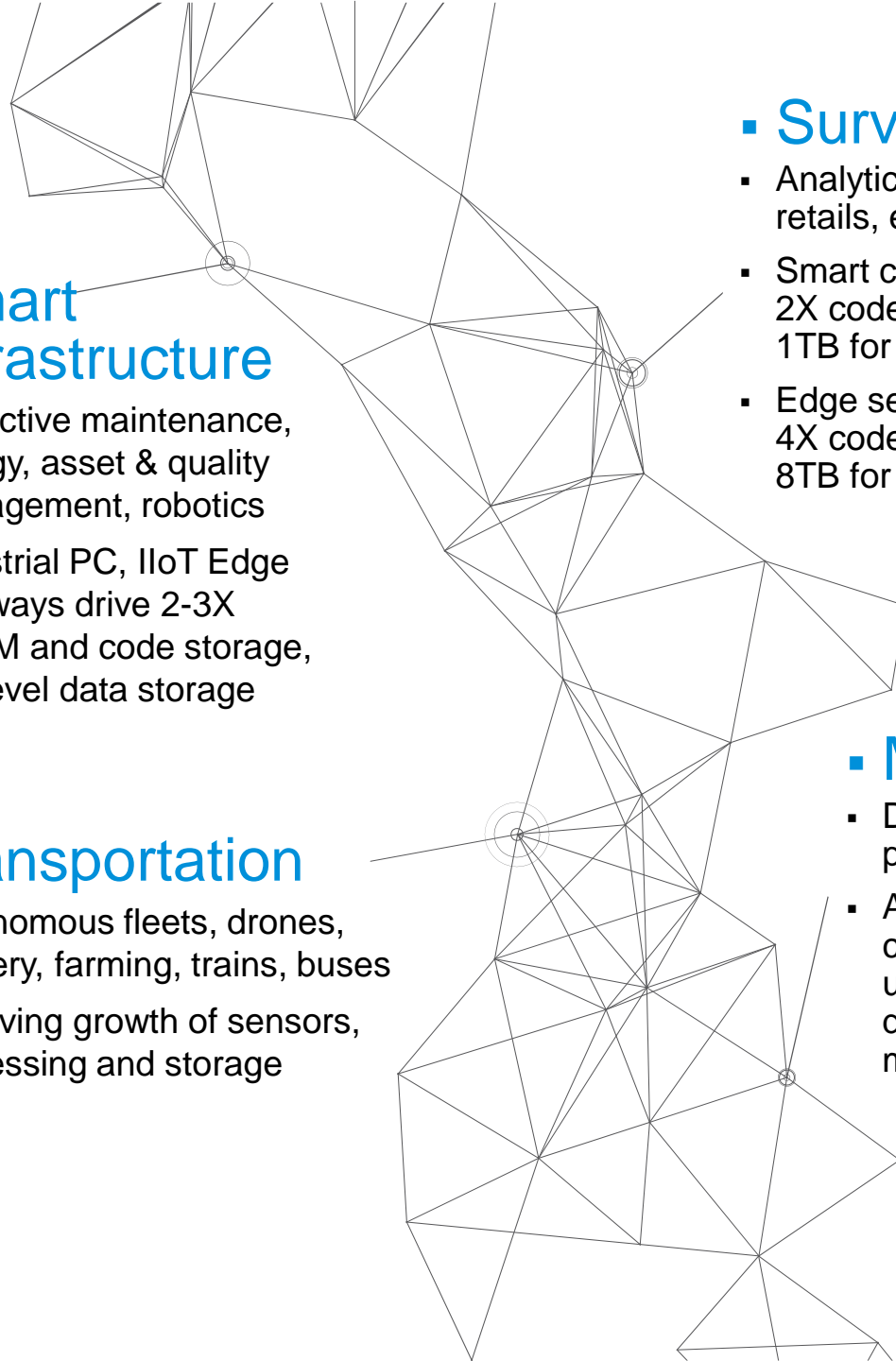
1 Source: Statistica   2 Source: MarketsandMarkets   3 Source: vxchnge

4 Source: Polaris Market Research   5 Source: Grandview Research

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AI: Sparking the Next Industrial & Infrastructure Revolution

Smart Infrastructure

- Predictive maintenance, energy, asset & quality management, robotics
- Industrial PC, IIoT Edge gateways drive 2-3X DRAM and code storage, GB level data storage

Transportation

- Autonomous fleets, drones, delivery, farming, trains, buses
- AI driving growth of sensors, processing and storage

Surveillance

- Analytics across cities, retails, enterprise, home
- Smart cameras – 8X RAM, 2X code storage and up to 1TB for data storage
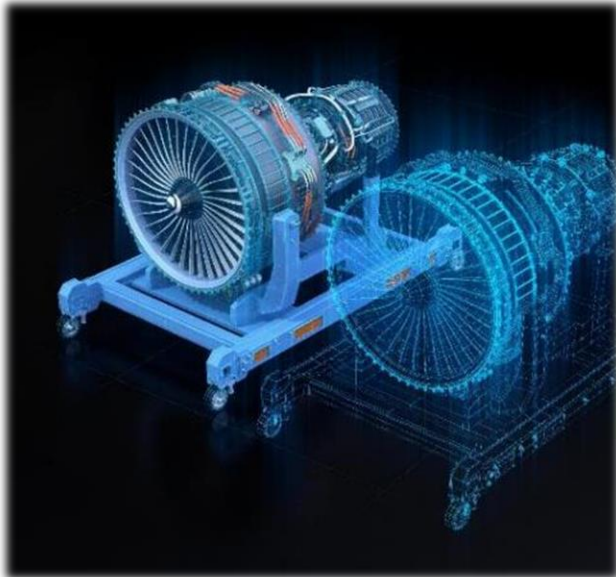- Edge servers – 2X cache, 4X code storage and up to 8TB for data storage

Medical

- Diagnostics, imaging, patient management
- AI growth driving GPU class machines with ultra-high-bandwidth/ density DRAM and multi-TB SSD storage

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Digital Twin Is A Great Concept
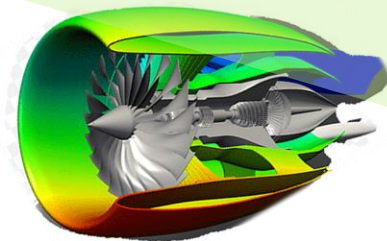
…but hype to reality is not simple

Every system is highly complex

Cyber-physical translation is complicated

Microsoft Azure

Analytics and Connectivity is costly

- Multiphysics simulation
- Real-time control loop
- Inference operation
- Machine vision
- Metadata
- others…

Featured	**Azure IoT Hub** — Connect, monitor and manage billions of IoT assets	**Azure IoT Edge** — Extend cloud intelligence and analytics to edge devices	**Azure IoT Central** — Accelerate the creation of IoT solutions
Compute			
Networking			
Storage	**Azure Digital Twins** — Build next-generation IoT spatial intelligence solutions	**Azure Time Series Insights** — Explore and analyze time-series data from IoT devices	**Azure Maps** — Simple and secure location APIs provide geospatial context to data
Web			
Mobile			
Containers	**Azure Functions** — Process events with serverless code	**Event Grid** — Get reliable event delivery at massive scale	**Azure Machine Learning** — Bring AI to everyone with an end-to-end, scalable, trusted platform with experimentation and model
Databases			
Analytics			
AI + Machine Learning			
Internet of Things	**Machine Learning Studio** — Easily build, deploy, and manage predictive analytics solutions	**Azure Stream Analytics** — Real-time analytics on fast moving streams of data from applications and devices	**Logic Apps** — Automate the access and use of data across clouds without writing code
Integration			
Identity			
Security	**Notification Hubs** — Send push notifications to any platform from any back end	**Azure Cosmos DB** — Fast NoSQL database with open APIs for any scale	**API Management** — Publish APIs to developers, partners, and employees securely and at scale
Developer Tools			
DevOps			
Management and Gover…			
Media	**Windows 10 IoT Core Services** — Long-term OS support and services to manage device updates and assess device health		
Migration			
Mixed Reality			
Blockchain			
Hybrid			

- GE jet engines collect information at **5,000 data points per second**
- Boeing 787 generates an average of **500GB of system data per flight**
- An Airbus A380 is fitted with as many as **25,000 sensors**

- Per Linux VM (per hr)
- Per storage block (per GB per month)
- Per Function (per Million executions)

" Azure Digital Twins is currently in public preview, and it's not recommended for production workloads "

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Evolving Industrie 4.0 Connectivity Architecture

The Intelligent Edge – Compute Moving Closer to Data Source

Ultra low latency analytics

Breaking down 'big data' to Intelligence

Reduce Cost of Connectivity

Layered Security & Safety

Sensing

Inference

Training
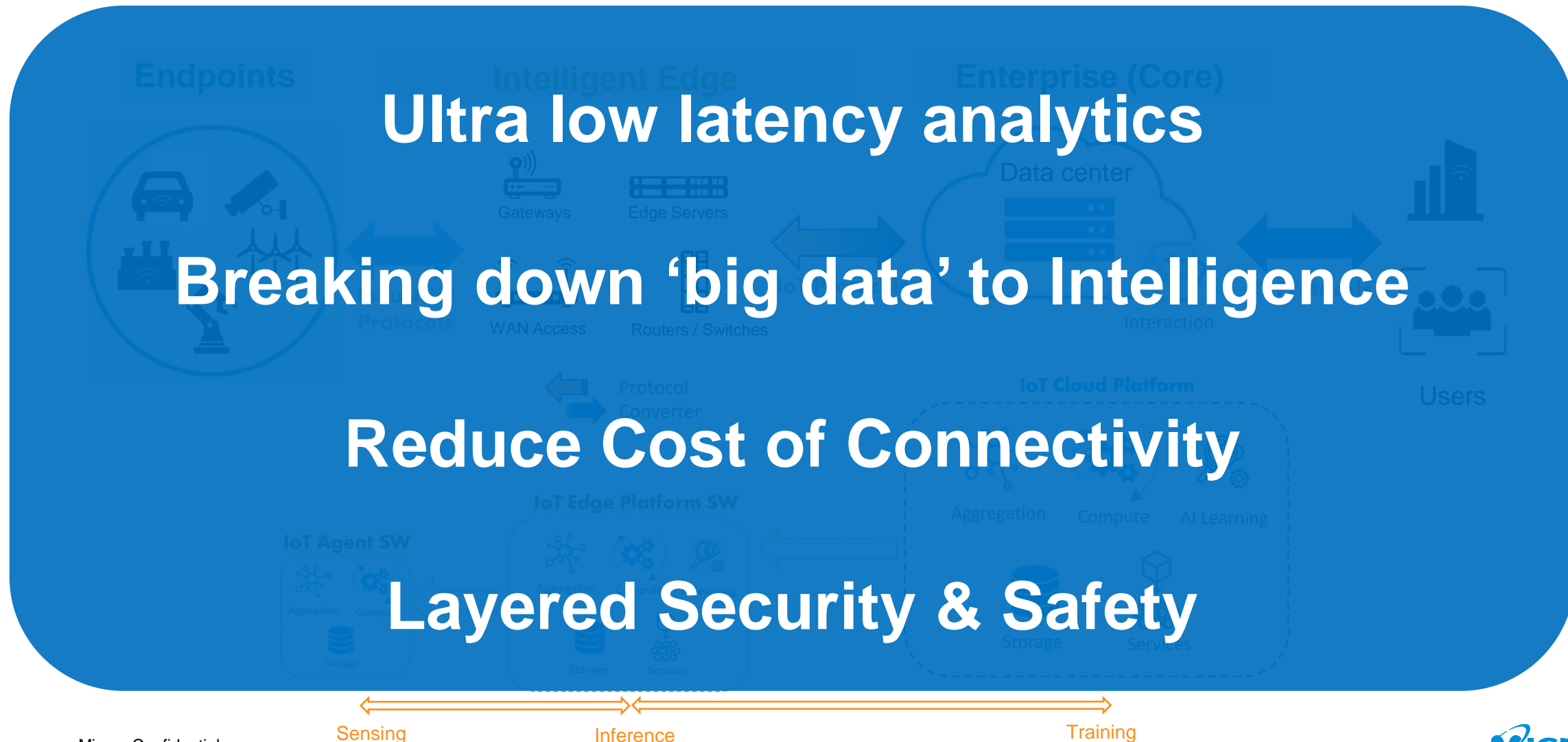
Market Dynamics Enabling the Industrie 4.0 Edge

Synergistic technologies, Interoperability Standards, and Business Value

Standards Toward Interoperability

- Chipsets with **Embedded HW AI/ML inference accelerators**
- **IoT Platforms** tailored for the Edge
- Adoption of **AR/VR** for industry
- **NFV** paradigms and use of containers and **Microservices**

Intelligence & Technologies at the Edge

- **RAMI 4.0 standards**
- De facto **End-to-end protocols**
- Standardizing **Physical Layer** (ex. TSN, single pair Ethernet)
- **LTE-A Pro, 5G, LPWA** adoption
- **RISC-V** ISA open architecture
- **Open RAN** and **uCPE**

- **Hybrid cloud** cost savings
- Success from **PoCs to Profits**
- Building in **layers against security threats**
- Opportunities for **new revenue streams**

Business Justification

Standardization Facilitates More Collaboration and Innovation

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Edge Architectures Will Grow in Complexity

Increasing Workloads Demand More Memory & Storage

Complex Edge Compute

Simple Edge Gateway

Microservices

Local Historian

Edge Analysis

Aggregate w/ Time function

Certify

Aggregate

Process

Forward

SW

HW

Application

Cloud Interface

Protocol Stacks

Security

Bare Metal OS/Middleware

I/O Interface | Multi-Core CPU | SRAM | NOR Flash | Peripherals | Connectivity

50x Lower Latency **75x** More Throughput

Compute demands at the Edge

2x → 200x

Code size Increase

MB → TB

Edge Storage Increase

Container Modules

Application Container | Application Container | Application Container

Cloud Agent | Platform Infrastructure | DBMS

Node Management | Protocol Stacks | AI Compute

Security

Bare Metal OS/Middleware

I/O Interface | Multi-Core CPU | DDR3/4 | NAND / NOR | eMMC, SSD | Peripherals | Connectivity | Inference Accelerators | HW Device Identity

*DLA – Device Level Accelerator

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5G Helps Industrie 4.0 to Transform Manufacturing

- 5G Ultra low latency enables

  - Collaborative robots to work alongside humans
  - Augmented Reality for operation and maintenance help

- 5G Massive Machine Type Communication enables

  - Wide deployment of sensors for predictive maintenance, monitoring, supply chain tracking

- Enhanced mobile broadband can support more bandwidth of data

- Smart factory can leverage from a hybrid cloud architecture with local DRAM and NAND solutions for fast data analytics at the edge
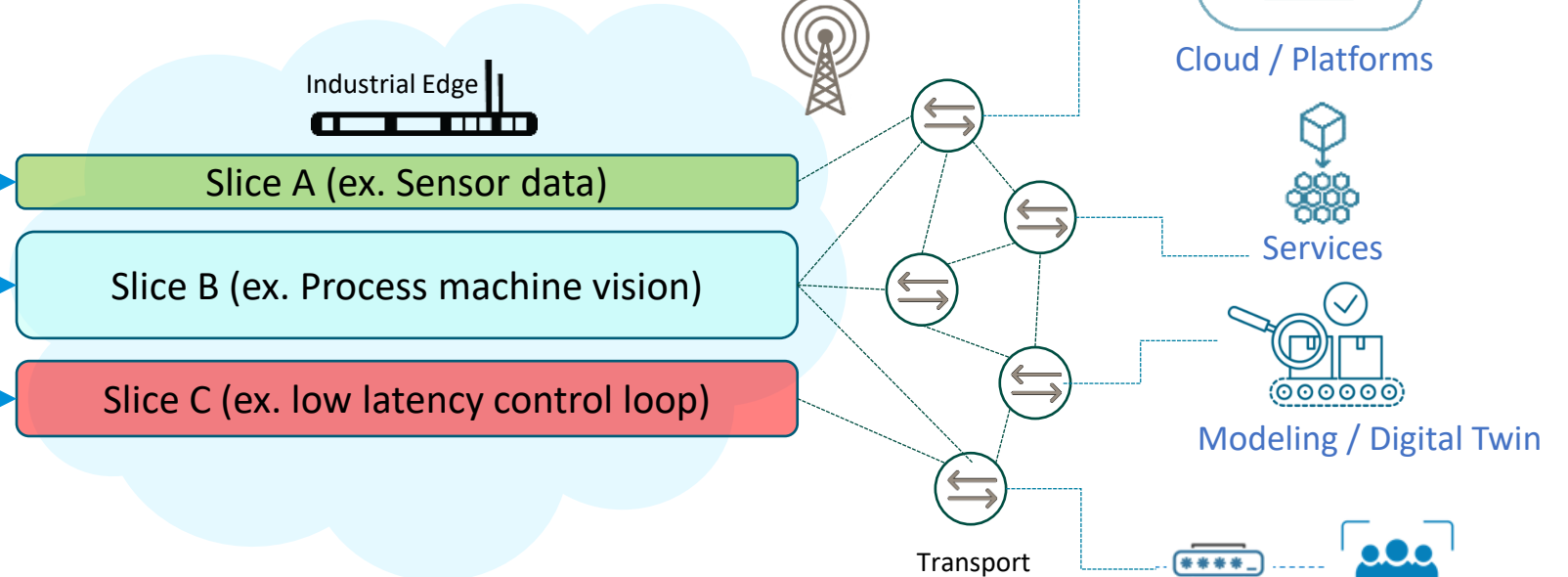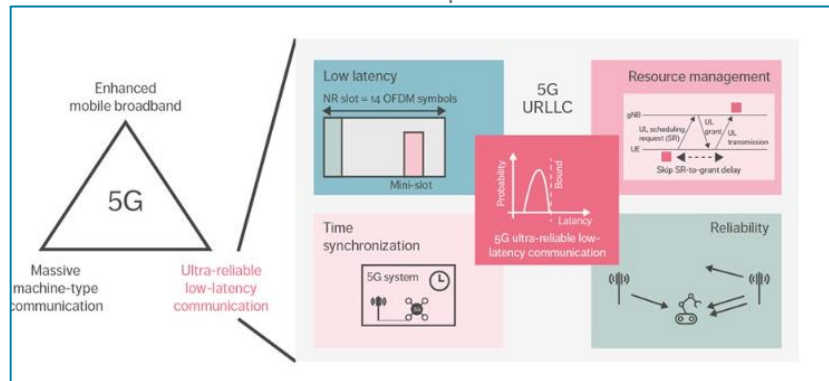
5G Network Slicing Allows for Data Synchronization

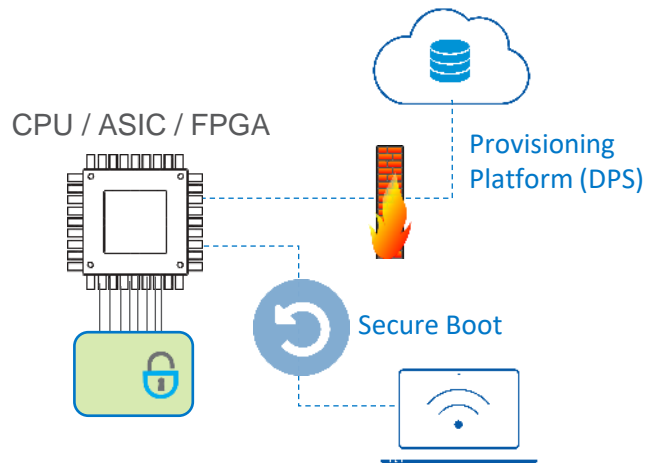URLLC function aligned to Industry 4.0 needs

Industrial Edge

Slice A (ex. Sensor data)

Slice B (ex. Process machine vision)

Slice C (ex. low latency control loop)

Transport

IEEE802.1 TSN

PLC / Controllers

Cloud / Platforms

Services

Modeling / Digital Twin

Access

Expertise

5G URLLC overview of TSN components

Enhanced mobile broadband

5G

Massive machine-type communication

Ultra-reliable low-latency communication

Low latency
NR slot = 14 OFDM symbols

Mini-slot

5G URLLC

Resource management

gNB
UL scheduling request (SR)
UL grant
UL transmission
UE
Skip SR-to-grant delay

Time synchronization

5G system

5G ultra-reliable low-latency communication

Probability
Bound
Latency

Reliability

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Security Considerations in a Connected Factory

Requirements within each phase of IIoT implementation

Hardware Root of Trust

CPU / ASIC / FPGA

Provisioning Platform (DPS)

Secure Boot

Secure Device On-boarding

Public Key Infrastructure (PKI)

Certificate Authority (CA)

Cloud Operation & Services

IIoT Edge 'Things'

Transport Layer Security (TLS)

Access

Applications & Services

Needs

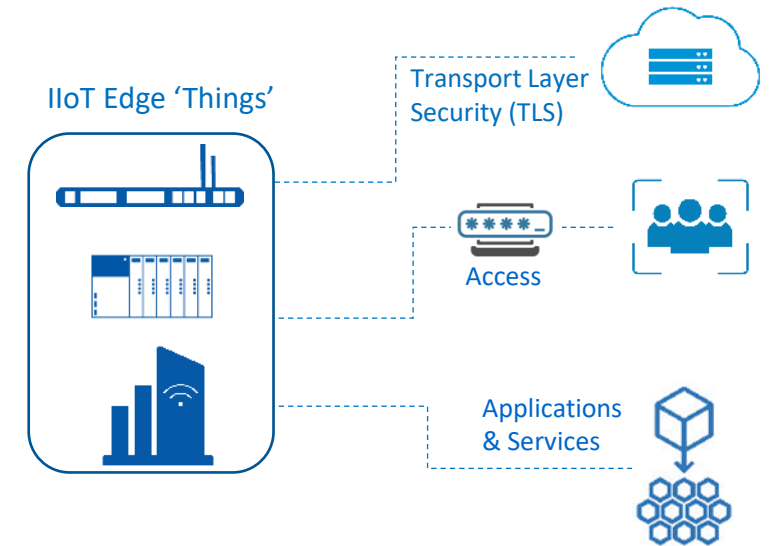- Unique credentials for each device
- Secure key storage
- Certificate-based identities
- IP/Firmware protection
- Secure boot and Debug lock
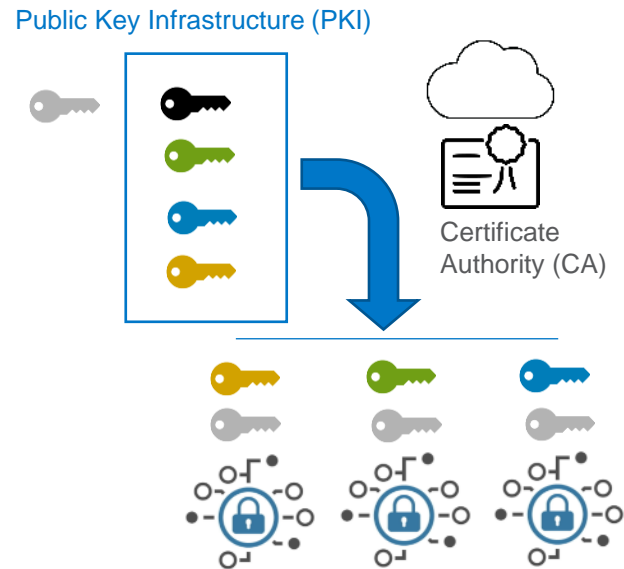
- Zero touch onboarding
- Remote attestation
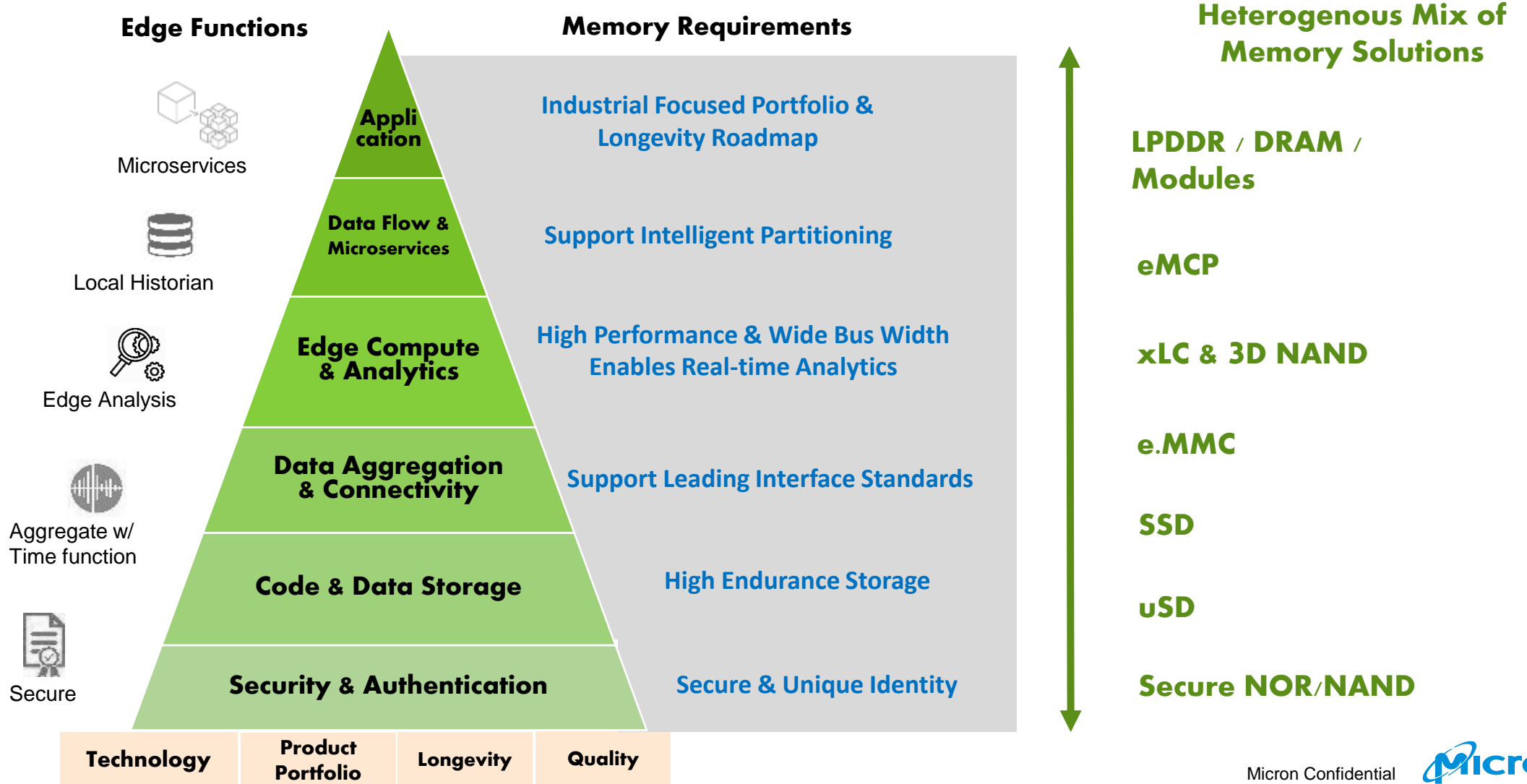- In-field device authentication
- Late binding – delivery of identity

- Over the air updates
- Transport layer security (TLS) protocols
- Secure access & anti-tamper
- Renewal/Revocation

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Memory & Storage Requirements To Support The Edge

Need for broad portfolio of memory solutions

Edge Functions

Microservices

Local Historian

Edge Analysis

Aggregate w/ Time function

Secure

Memory Requirements

Application — Industrial Focused Portfolio & Longevity Roadmap

Data Flow & Microservices — Support Intelligent Partitioning

Edge Compute & Analytics — High Performance & Wide Bus Width Enables Real-time Analytics

Data Aggregation & Connectivity — Support Leading Interface Standards

Code & Data Storage — High Endurance Storage

Security & Authentication — Secure & Unique Identity

Technology | Product Portfolio | Longevity | Quality

Heterogenous Mix of Memory Solutions

LPDDR / DRAM / Modules

eMCP

xLC & 3D NAND

e.MMC

SSD

uSD

Secure NOR/NAND

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Micron Delivers Complete Edge Essentials

Extensive DRAM solutions for Compute Needs at the Edge

- DDR3/DDR4 & LPDDR4x: market proven; best system cost/performance tradeoff
- LPDDR5x with data rates up to 8.5 Gb/s; improved power efficiency; up to x64 bus width packaged solutions allows high bandwidth interface for AI/ML workloads
- Long term support on DRAM and LPDRAM
- Extensive DRAM module offerings

Broad NOR/NAND portfolio for code & data storage versatility

- SLC NAND with adaptive FTL; on-die ECC; industrial temp range; OTP data protection
- Xccela™ Flash – combines x8 (Octal SPI) SDR/DDR speed interface with up to 2Gb full-featured flash; supports XiP up to 400MB/s (3.2Gbps) reads; reducing pin count 4x, energy consumption by 3x*
- e.MMC with internal NAND management simplifies development
- Award Winning** 1TB uSD removable storage
- Robust hardware-based security features in flash

Multichip (MCP) package solutions for space constrained devices

- 30-40% savings on board space through vertical stacking at die-level or PoP
- NAND MCP: up to 8Gb NAND with 8Gb LPDRAM
- e.MCP: up to 16GB e.MMC with 16Gb of LPDRAM
- Low 1.8V Power in Small Package Size/Ball Count Solutions

*Compared with page mode parallel NOR   **SIA New Product Showcase, 2019

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Storing Critical Data at The Edge

Industry's First 1TB Automotive & Industrial Grade PCIe NVMe Flash Storage

Micron 2100AI and 2100AT 3D TLC SSD

Superior performance:

- >2X faster reads and >1.5X faster writes than UFS 2.1 and SATA 3

Highest capacity in small form factor:

- 64GB to 1TB densities
- 16x20mm BGA and 22x30 M.2

Operating temperature:

- -40C to 105C

Storage interface:

- PCIe Gen3 x4, NVMe 1.3 with direct boot option

Edge Application Benefits:

- End to end data path protection
- SLC intelligent partitioning
- TCG* Opal self-encrypting drives (SED) compliant
- Robust local storage optimizes DBMS operation
- Efficient power management

Quality and reliability:

- AEC-Q100, IATF 16949-compliant

*Trusted Computing Group consortium

Edge Device Memory Profiles

	C-IoT / M2M	IIoT Edge Gateways & Routers	Edge Controllers	Enterprise IoT Edge Servers
Compute & Connectivity	MCP (SLC NAND+ LPDDR2/3/4) LPDDR3, LPDDR4	SDRAM DDR3 LPDDR4	SDRAM DDR3/L DDR4 SODIMM DDR4/L	SDRAM DDR3/L DDR4, DDR5 SODIMM/UDIMM DDR3 L/DDR4
Code, Boot, Data, Services Stack	MCP4 NOR standalone	xLC NAND QSPI NOR	NAND QSPI NOR eMMC	NAND QSPI NOR eMMC
Storage	eMCP	eMMC SSD: 4 to 128 GB SD/MMC option: up to 512GB	SSD: 8 to 256 GB SD/MMC option	SSD: 128GB to 2TB M.2 interface PCIe and SATA
Security	TLS, Software/protocol based	On-chip	On-chip, TPM	On-chip, TPM

Note: Example memory profiles per device type (does not represent all combinations and densities)

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