CAICT 中国信通院

工业互联网产业联盟
Alliance of Industrial Internet

Progress and Practices: Industrial Network Connectivity Technology

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01. Alliance of Industrial Internet (AII)

02. Development of industrial connectivity technologies

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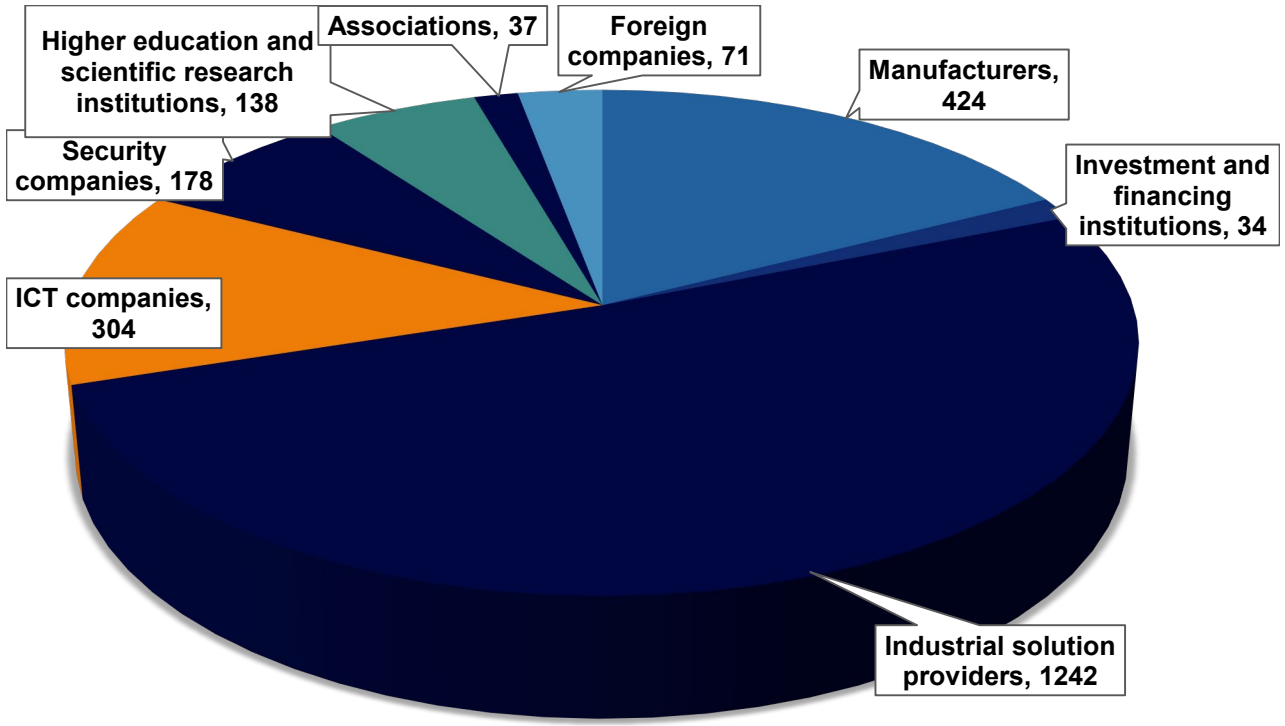
AII: The largest ecosystem platform for China's industrial Internet

On February 1, 2016, the Alliance of Industrial Internet (AII) was established under the guidance of China's Ministry of Industry and Information Technology (MIIT). As of December 2022, the AII had **2,428** members.

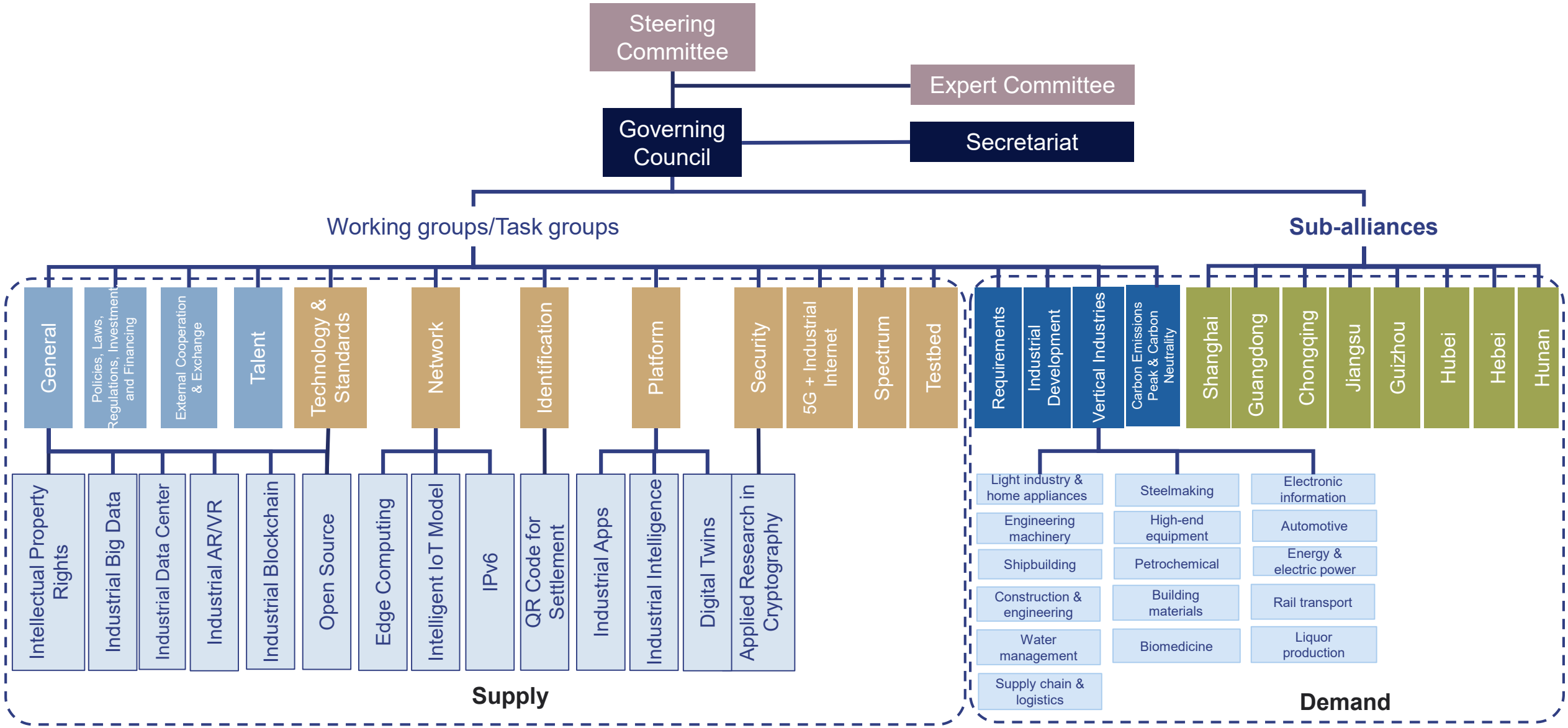


Member sectors

The AII consists of members from **80+** sectors, including telecom, radio, TV, and satellite transmission services; electricity and heat production and supply; coal mining and washing; oil and gas exploration; metal products; ferrous metal smelting and calendering; automotive manufacturing; railway, ship, aerospace, and other transportation equipment manufacturing; pharmaceutical manufacturing; food production; rubber and plastic product manufacturing; ecological protection; chemical raw materials and chemical manufacturing; environmental governance; software and IT services; Internet and related services; general-purpose equipment manufacturing; computer, communications, and other electronic equipment manufacturing; special-purpose equipment manufacturing; manufacturing of other equipment; monetary and financial services; and press and publishing.

The AII brings together industry players from across the globe to comprehensively support the digital transformation of businesses of all sizes in China.

16 + 14 + X structure



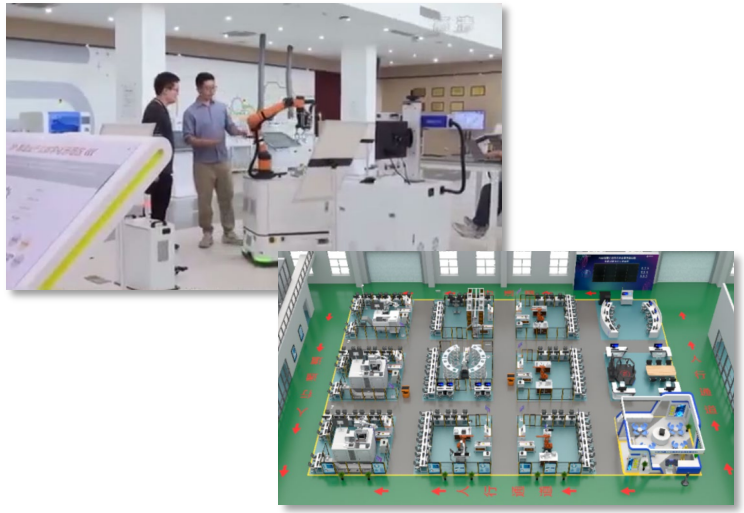
The AII is innovating nonstop, with many achievements

127 **white papers and reports**

Standards

75 **released**

170+ **pending release**



27 **labs**

19 practice bases

The AII has selected ***79*** testbeds, ***10*** star testbeds, ***127*** use cases of industrial Internet, ***67*** use cases of industrial apps, ***13*** use cases of industrial intelligence, ***10*** use cases of industrial data centers, ***5*** use cases of industrial blockchain, ***19*** use cases of information models, ***20*** use cases of supply chain digitalization, ***11*** use cases of industrial Internet open source, ***20*** use cases of digital tech for carbon neutrality, ***6*** use cases of industrial Internet for smart water management, ***58*** network solutions, ***47*** security solutions, and ***87*** industrial Internet platforms, all of which have passed trusted platform service assessments and functional evaluations. The AII is committed to driving the adoption of industrial Internet technologies.

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Industrial Revolutions drive industrial network upgrades

Industry 2.0: Electrification, marked by the wide use of electric power

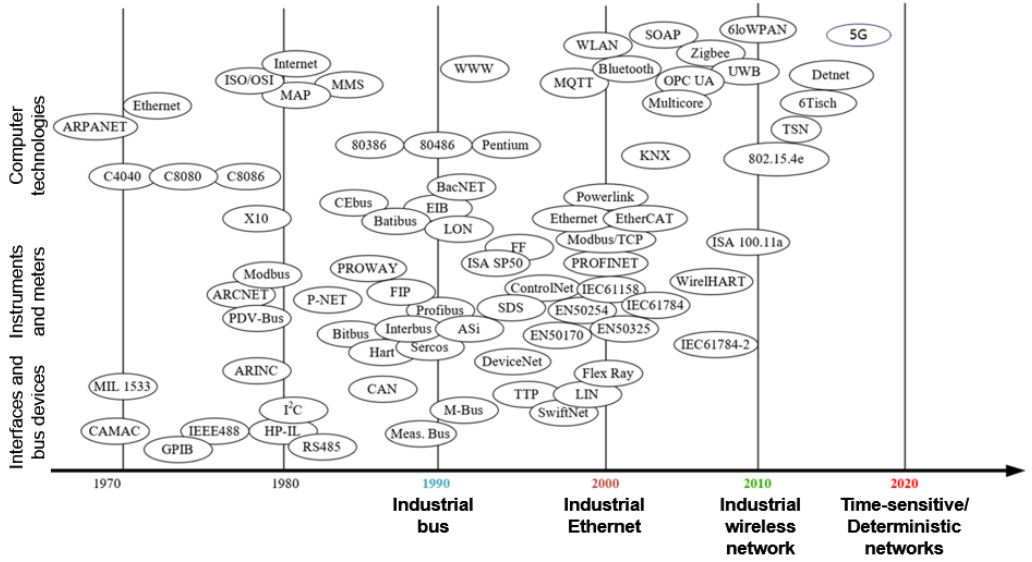
- **Industrial Network 1.0:** Production control networks, based on analog signal communication, mainly used for basic automatic control devices in production systems during the 2nd Industrial Revolution

Industry 3.0: Automation, marked by the use of PLC and PCs

- **Industrial Network 2.0:** Fieldbus control systems and industrial Ethernet, based on digital communication, mainly used for digital industrial devices and automatic control systems in workshops during the 3rd Industrial Revolution

As the industrial Internet advances, the industrial sector is becoming increasingly intelligent, automated, and integrated. Driven by applications in new fields, such as AI, VR, and green manufacturing, the industrial network is experiencing a new technological revolution.

Technologies featuring high performance, intelligence, and convergence, such as 5G and time-sensitive networks (TSNs), are now the cornerstone of new-generation industrial networks.



Full industrial network connectivity brings new challenges

The ISA-95 hierarchical architecture of industrial networks cannot meet the innovation requirements of industrial Internet applications

- Services that demand high network performance are emerging, such as ultra-long-distance machine control, immersive online production management, industrial digital twin, machine-learning-based predictive maintenance, and machine-vision-assisted quality inspection
- There is a growing need to reconstruct and upgrade existing services, such as motion control, predictive maintenance, and cloud migration of enterprise services

Industrial network scale rapidly expands as industrial enterprises embrace digital transformation

- Innovative applications of the industrial Internet have far higher data transmission rates, for example, 8K machine-vision-assisted/XR immersive online fault diagnosis
- The popularization of smart machines, sensors, and identifiers is causing a sharp increase in the number of network terminal connections and connection density.

Lack of a comprehensive system for evaluating network service quality for industrial Internet

- Networks are still being designed for human cognition, despite machines possessing superior capabilities in audio, video, and control response.

The growth of industrial Internet service data increases the energy consumption of industrial networks

- By 2030, the traffic generated by digital services will reach 612 ZB, 13 times that of 2020. (Source: Digital Economy Compass 2020, Statista)
- With the ongoing growth of energy needs, energy consumption and corresponding carbon emissions will increase 2.3 times. Therefore, the ICT industry must reduce carbon emissions by at least 45% by 2030. (Source: ITU-T L.1470 Recommendation)

Key aspects of Industrial Network 3.0

Industrial Network 3.0 is driven by new industrial Internet paradigms and business models. It supports innovative applications capable of people-machine-platform collaboration. It also features highly convergent technologies, flexible deployment, measurable services, and programmable interfaces.

Quality of service (QoS) is at the core of services:

- Deterministic assurance for million-level connection capability, 10 Gbit/s connection rate, and microsecond-level latency/jitter
- Heterogeneous network resource collaboration; intelligent optimization of service quality
- Establish a fully connected network featuring wired + wireless, real-time + non-real-time, and LAN + WAN

Driving forces

Technological evolution towards full connectivity between people, machines, and platforms

- Transmission of industrial control information of production lines → Converged bearing of multiple types of integrated service traffic
- Field data → Interconnected and interoperable industrial knowledge
- Industrial wireless networks evolve to provide high bandwidth, high deterministicity, and low jitter
- Industrial wired networks evolve to provide high deterministicity, reliability, and flexibility

Visions of Industrial Network 3.0

Ubiquitous interconnection as the basic requirement

- Full network coverage and connection of Man, Machine, Material, Method, Environment, and Measurement (5M1E)
- Ubiquitous security becomes inherent to industrial networks

Intelligence and simplicity as essential requirements

- Intelligence throughout the lifecycle, with capabilities such as sensing, analysis, decision-making, and deployment employed throughout network planning, deployment, O&M, and optimization
- Service interfaces streamlined based on data, scenarios, and algorithms, simplifying the interfaces between people and systems

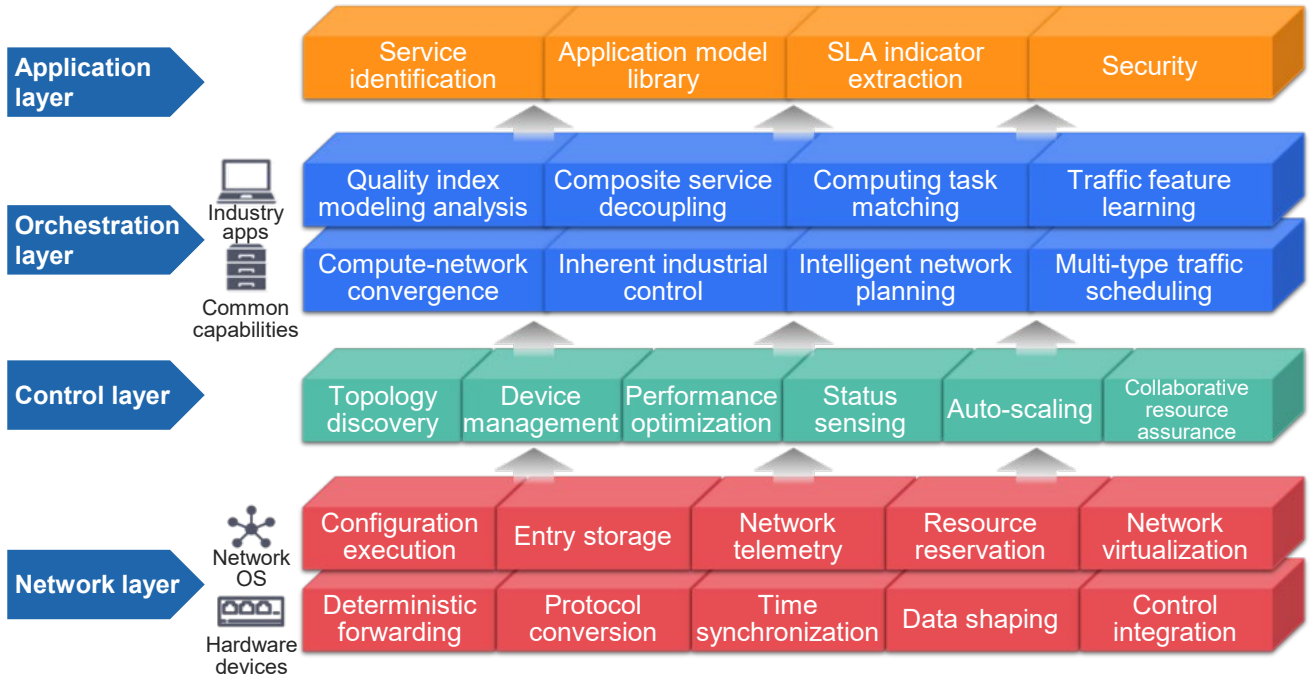
Deterministic bearer as the core requirement

- New network technologies used to implement end-to-end converged bearer
- Multi-level, wide-range deterministic transmission

Pursuing high efficiency and low carbon

- New forwarding and control technologies used to improve network capabilities to adapt to various industrial applications. One network used for multiple purposes, reducing the need for repeated construction
- Energy-saving technologies used to achieve high energy efficiency at the device, network, and system levels

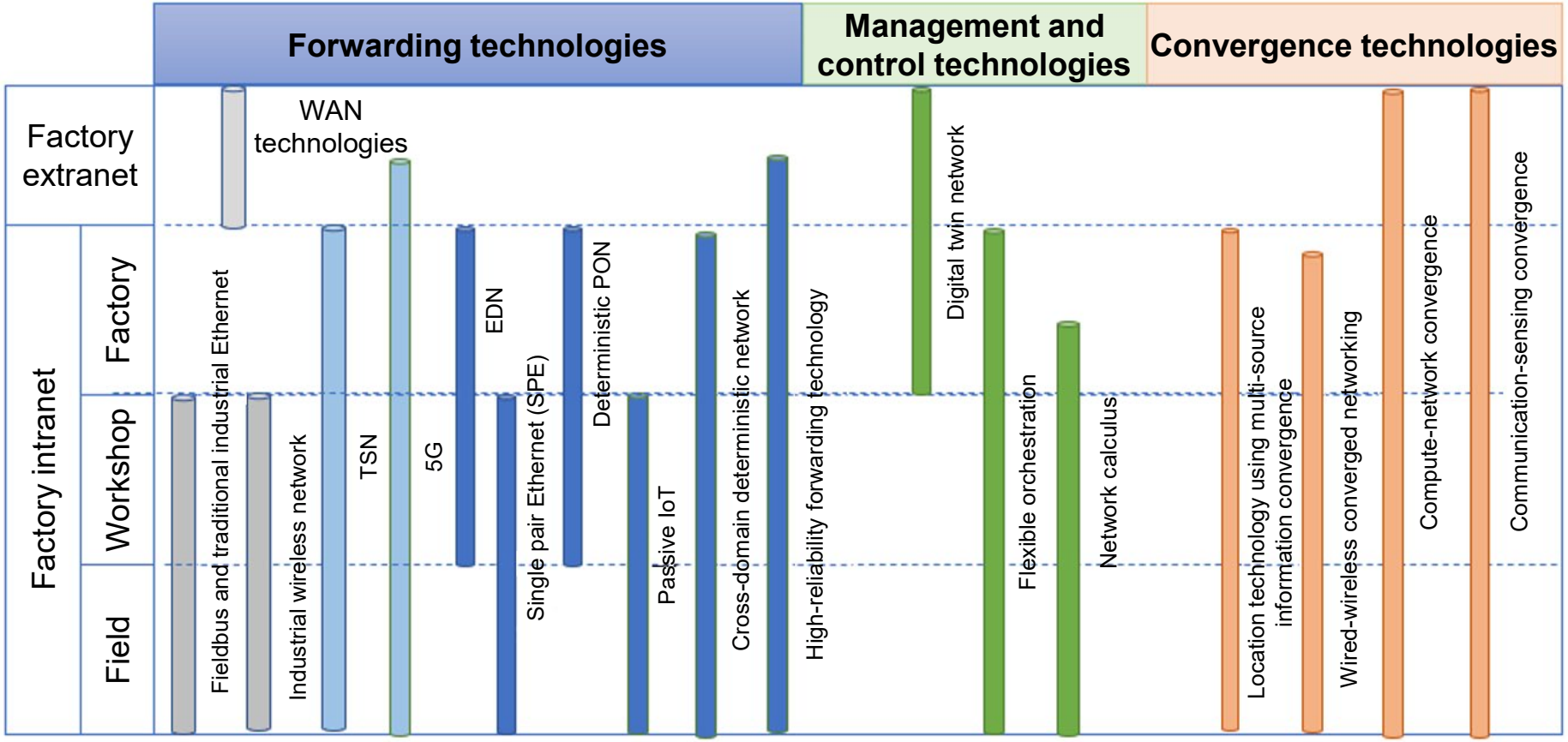
Functional architecture of Industrial Network 3.0



Functional architecture of Industrial Network 3.0

- **The application layer** identifies the requirements raised by upper-layer services and converts them into various service indicators within the industrial network.
- **The orchestration layer** consists of:
  - **Industry application platform:** Based on the specific requirements identified by the application layer, this platform breaks down complex tasks, establishes unique traffic models for different services, and monitors service and network quality based on service indicators.
  - **Common capability platform:** This platform integrates industrial control capabilities, as well as computing and network resources, within a single unified view and intelligently orchestrates them based on traffic models in order to realize an adaptive network.
- **The control layer** detects the current network status, manages network resources across domains, and manages and configures network devices based on network orchestration results in order to provide resource assurance for upper-layer services.
- **The network layer** provides the basic functions of an industrial network.
  - **The network OS** follows the instructions of the control layer to adjust and monitor device configuration, and implements functions such as network telemetry and resource reservation.
  - **Hardware devices** ensure the deterministic forwarding and real-time mode conversion of networks from the hardware level, and integrate industrial control capabilities into network devices.

New technology system supports the implementation of fully-connected factories



Key technology map of Industrial Network 3.0 Source: Industrial Network 3.0 White Paper

- **The forwarding plane targets deterministic bearing and depends on the evolution of technologies such as 5G, TSN, deterministic PON, single pair Ethernet (SPE), passive Internet of Things, cross-domain deterministic network, high-reliability forwarding technology, and enhanced deterministic networks, to build inherently deterministic bearer networks.**
- **The management and control plane targets openness and autonomy, and depends on technologies like network calculus, compute-network convergence, and digital twin networks to evolve intelligent and native network O&M technologies.**
- **The convergence plane aims to improve industrial application service experience, and depends on converged communications information technologies, such as compute-network convergence, communication-sensing convergence, multi-source information convergence, and wired-wireless convergence networking, to promote the continuous improvement of network service capabilities and experience.**

All is actively promoting the implementation of new technologies such as 5G, TSN, and industrial PON to support enterprises in building fully connected factories.

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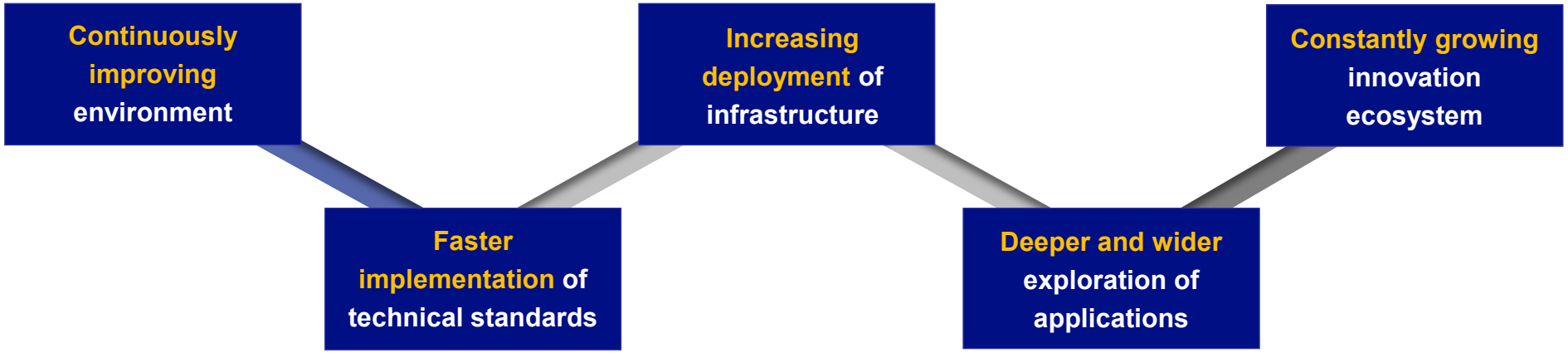
5G driving upgrades in industrial connection capabilities

China's "5G + industrial Internet" made major progress

- **MIIT:** New Three-Year Action Plan (a priority in deployment)
- **Local:** **31** provinces have formulated 5G policies, and **more than 80%** of regions have specified "5G + industrial Internet" policies

- **2.22 million** 5G base stations deployed by the end of Sep 2022
- **Three networking modes:** VPN, hybrid VPN, and standalone private network

- **16** All testbeds
- **Over 3600** registered enterprise users in the project library



- Continuously improve the "5G + industrial Internet" standard system
- **8** industry standards (ports, mines, etc.) under development
- **2** All standards released, with **12** projects under development

- Over **4000 projects** under construction across China
- **10 key industries** (equipment manufacturing, steel, ports, etc.)
- **20 typical scenarios** (design, manufacturing, testing, etc.)

5G technology will help upgrade field devices in scenarios such as cloud-based device deployment, wireless device reconstruction, and edge intelligent applications. It will also provide **new paths, methods, and models** for the digital transformation of industrial enterprises, and can address the aforementioned problems.

From the 512 Project to construction of 5G-connected factories

"5G + Industrial Internet" 512 Project Promotion Scheme 2019

- All industry players shall jointly promote the innovative development of "5G + industrial Internet" through close cooperation and active exploration.

10 Typical Application Scenarios and 5 Key Industry Practices of "5G + Industrial Internet" 2021

- Develop 20 typical application scenarios in 10 key industries and make key progress.

Typical scenario development → Integrated solutions

Reference Guide for Constructing 5G-connected Factories

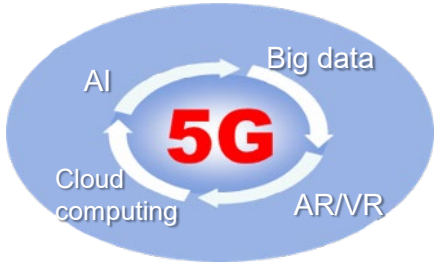
- The Guide aims to further accelerate the adoption of new technologies, scenarios, and models of "5G + industrial Internet" in all domains and procedures of industrial production.
- Promote quality improvement, cost reduction, efficiency enhancement, environmental friendliness, and safe development across traditional industries.
- Drive the development and expansion of the 5G technology industry.
- Guide regions and industries to build 5G-connected factories.

On September 4, 2022, the Reference Guide for Constructing 5G-connected Factories was officially released.

5G-connected factories are key to the development of "5G + industrial Internet"

5G-connected factories

- Leverage **new information technologies**, especially 5G



New or reconstructed production facilities

Production lines, workshops, factories, etc.

- **Full connectivity of production units**
- **Deep integration of IT and OT**
- **Full utilization of data**
- **Efficient enablement through innovative applications**

Advanced factory

- Build **new infrastructure** for the industrial Internet

5G **connected** **factories**

- Organically integrate new ICT technologies, including **5G** (the key) and **others**
- Promote connectivity where possible and favorable, **but not the connectivity of everything**, and make adjustments based on actual situations and local conditions
- Focus on factories, **not just in the manufacturing sector** but also in mines, ports, electric power, and other sectors

Types of 5G-connected factories by sector

Sectors

Encourage sectors to build 5G-connected factories by incorporating the common technologies and methods of "5G + industrial Internet" into their operations and developing a variety of applications

Electronic equipment manufacturing

Equipment manufacturing

Steel

Mining

Electricity

Petrochemical and chemical

Construction material

Port

Textile

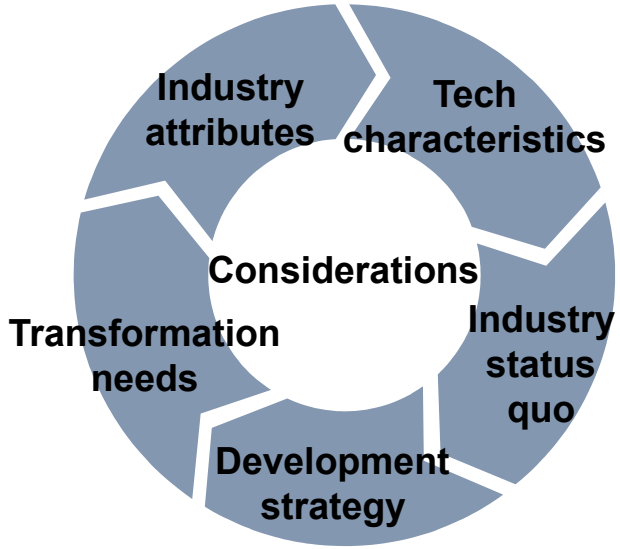
Home appliance

- Focus on the ten key sectors where **"5G + industrial Internet" is already being effectively applied**, and take the lead in promoting the construction of 5G-connected factories.
- Encourage enterprises with **high levels of automation, digitalization, and networking** to rapidly explore how to build 5G-connected factories.

Levels of 5G-connected factories

Levels

Encourage businesses to apply 5G to their production lines, workshops, and factories, leveraging 5G to upgrade production facilities and boosting 5G adoption at both the core and peripheral layers



- ☑ Production lines
- ☐ Workshops
- ☐ Factories

Production line level

Focus on equipment connectivity, data collection, and 5G converged application innovation within individual production lines or business units

Workshop level

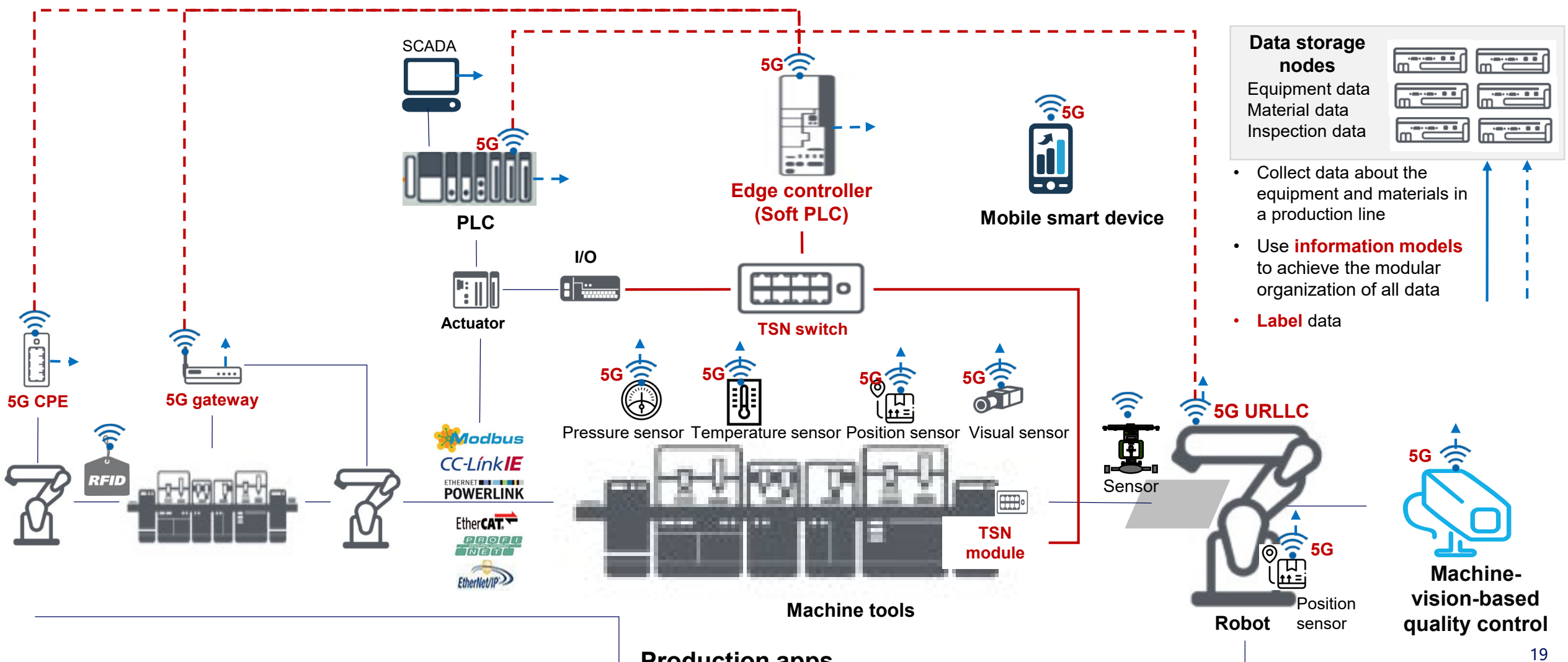
Focus on collaborative optimization and integrated innovation across multiple production lines and systems

Factory level

Improve connectivity across workshops and management levels to increase total factor productivity

Production line level

Focus on **equipment connectivity**, **data collection**, and **5G converged application innovation**



Workshop level

Focus on **collaborative** production across **multiple production lines and systems**, and enhance data streamlining and system integration

- Collect data about the equipment, materials, monitoring devices, and workers in a workshop
- Use **information models** to achieve the modular organization of all data
- **Label** data

Indoor 5G network

Data storage nodes

Equipment data
Material data
Inspection data
Monitoring data
Logistics data

Inspection and monitoring apps

Visual dashboard

5G

Inspection sensor

Video surveillance

Edge gateway
(Cloud-based control functions, AI functions, data cache, and production control apps)

Industrial gateway (incl. TSN modules)

5G/TSN gateway

(Industrial Ethernet networking)

(TSN)

Intelligent tally in the factory

Intelligent logistics in the factory

Production line 1

Production line 2

Production line 3

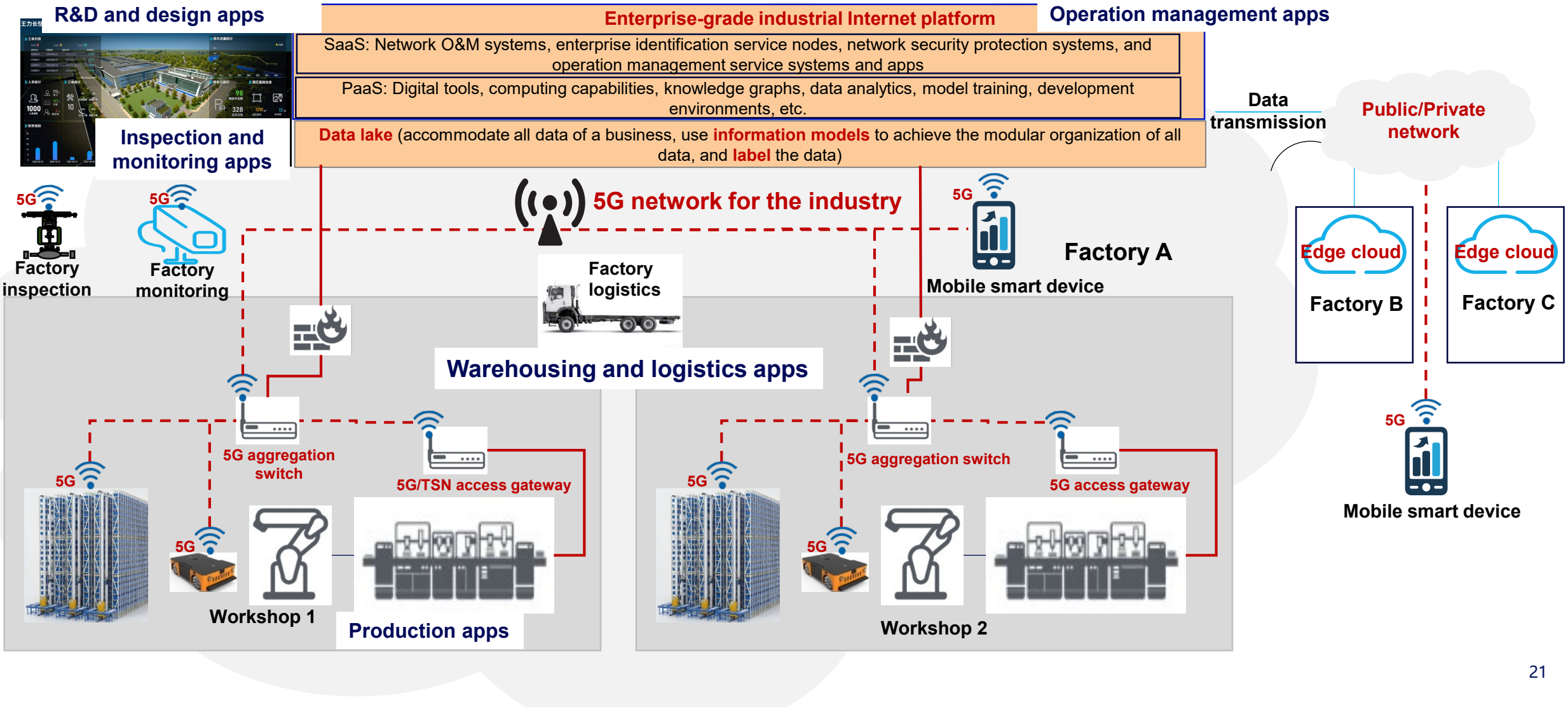
Mobile smart device

Warehousing and logistics apps

Production apps

Factory level

Improve connectivity **across workshops and management levels** to optimize production, operation, and management



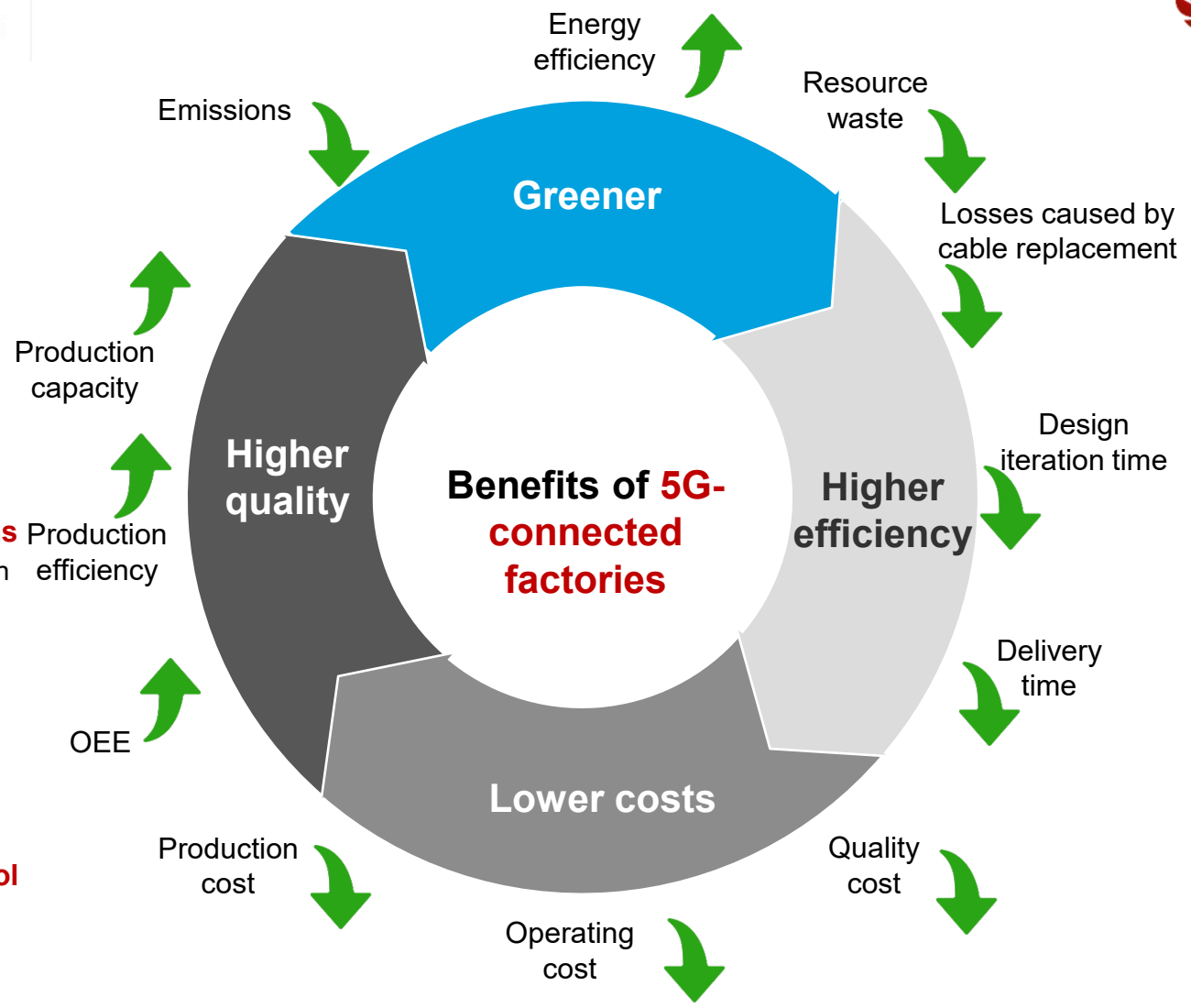
Benefits of 5G-connected factories

极氪 China unicom中国联通

Geely ZEEKR 5G-connected factory

5G hybrid private network, 5G intelligent network O&M platform, 5G + industrial Internet platform, and 12 typical 5G application scenarios

- **5G and AR for guiding operations**
  - More efficient design and mfg. collaboration
  - Annual costs down CNY20 mn
- **5G and AI for quality control**
  - QC staff down 80%
  - Non-conformance rate down 30%
  - QC accuracy up to >99%
- **5G and AR for O&M**
  - O&M efficiency up >50%
- **5G and AGV for teamwork control**
  - More efficient workshop management
  - Annual operating costs down CNY15 mn



HUAWEI 中国移动 China Mobile

Midea 5G-connected factory in Jingzhou, China

One 5G network for all services

Large-scale application of 5G

- 2,500+ devices in phase 1 of project
- 15 applications: 5G for AGV scheduling, 5G and AI for quality control, 5G for scheduling forklift trucks, etc.
- Avg. daily traffic: 20 TB

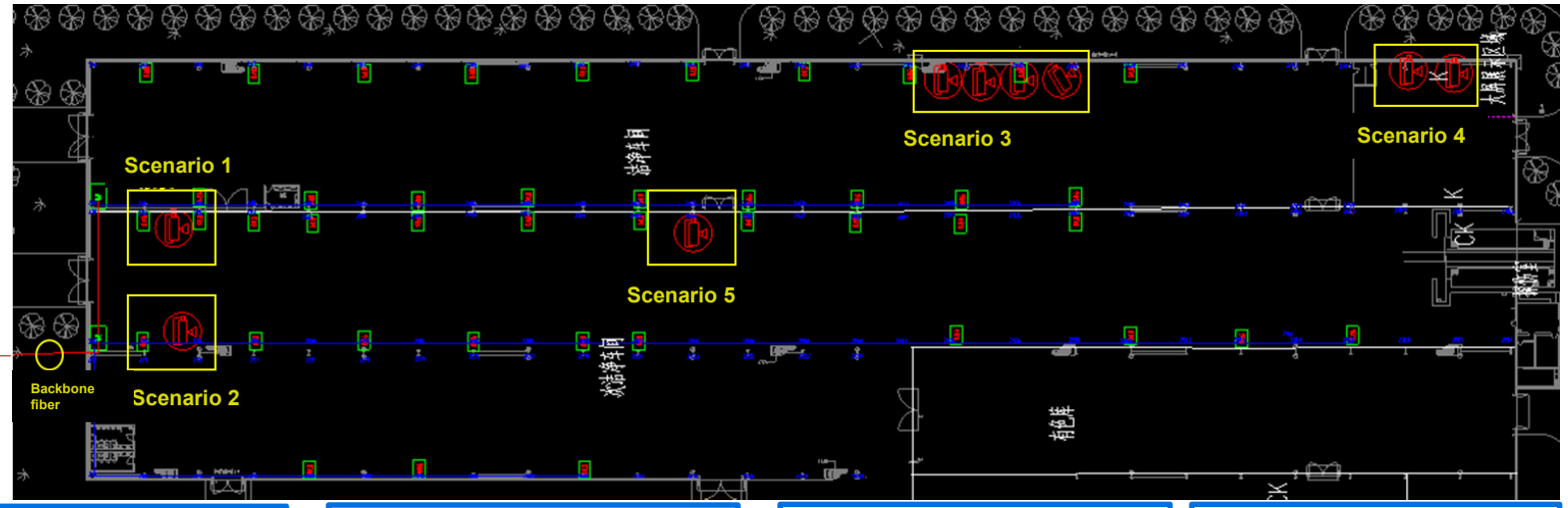
Lower costs, higher quality, higher efficiency

- Higher efficiency: Washing machine assembled in 15 seconds
- Make-to-order: Inventory down 50%
- Labor cost per product down 30%

Multiple technologies support fully connected factories

One high-end manufacturer has employed TSN to achieve upgrades in 5 typical scenarios, ensure full connectivity in its welding workshop, and merge its IT and OT networks.

Traffic of high-priority real-time industrial control, low-priority real-time video surveillance, and non-real-time data collection is transmitted over the TSN workshop network.



Scenario 1: Argon arc welding + Plasma welding
1 welding machine + 1 camera + 1 industrial computer

Scenario 2: Argon arc welding + Plasma welding
1 welding machine + 1 camera + 1 industrial computer

Scenario 3: Tube to tube sheet welding
4 welding machines + 4 cameras + 1 industrial computer

Scenario 4: Overlay welding
2 welding robots + 2 cameras + 1 industrial computer

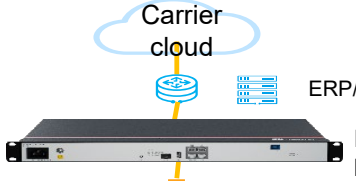
Scenario 5: Overlay welding within small tubes
1 welding machine + 1 camera + 1 industrial computer

Remote server: Machine learning
Store, train, and optimize key parameters of welding equipment

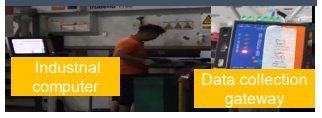
One precision machining company has leveraged FTTR optical industrial network technology to support its digitalization, enhancing quality and efficiency.

Pain points: Legacy network hinders digitalization

- Numerous network faults; difficult to perform fault delimitation
- No full-time IT staff; weak troubleshooting skills
- Multi-level switch networking; lack of topology info.; difficult to increase bandwidth



Linkage of machines/data collectors and MES

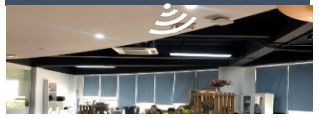


Order-based precision manufacturing

AGV logistics/indoor positioning

Smart warehousing for higher inventory turnover

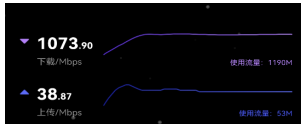
Full Wi-Fi coverage in offices



Office network speed: >1,000 Mbit/s

Reversible-plug Type C

Gigabit Wi-Fi



<1 ms latency

帧长	速率(%)	Average S&F (us)
64	75.19	64.93
128	76.81	68.582
256	78.00	80.31
512	78.56	93.338
1024	78.50	120.174

All scenarios covered

Smooth data transmission

- **Required warehouse space down 90%**
- **Costs down 10%**
- **Profits up 160%**

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Thank you