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How 5G And Edge Computing Advance IoT Value

This Dynamic Duo Dramatically Expands IoT Insights And Speed

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Research insights agenda

Emerging 5G networks promise latency and bandwidth benefits

5G powers IoT, automation, and edge computing

Edge computing transforms captured data into intelligent insight

5G and edge market adoption and key use cases

Vendor landscape

Recommendations

Emerging 5G networks extend edge and IoT opportunities but will take time to reach users

- 5G networks promise exponential improvements in connectivity speed, capacity, and latency to address IoT, automation, and edge use cases in specific industries.

- Currently, public 5G network availability is limited because telcos must invest in deploying new local network infrastructure on a block-by-block, city-by-city basis.

- 5G network spectrum characteristics make coverage, bandwidth, and latency tradeoffs.

- Low-frequency spectrum offers wider coverage, travels farther, and provides in-building coverage at the expense of supporting low data rates.

- High-frequency spectrum (e.g., millimeter wave) covers shorter distances and offers high data rates but is prone to distortion from buildings, rain, walls, and other elements that cause wave interference.

- 5G networks expand edge compute scenarios by distributing data and services where they can best optimize outcomes in IoT-enabled assets and connected environments.

5G technical specifications promise to enhance bandwidth, latency, and performance

5G feature	Feature description	5G feature specification	4G feature specification
Broadband speed	Maximum data transmission rate per user across coverage area	20 Gbit/s to 100 Mbit/s	100 Mbit/s to 10 to 15 Mbit/s
Latency	Time to transmit a data packet from one node to another	1-5 milliseconds	5 to 50 milliseconds
Stable performance under high-speed mobility conditions	Quality handover interruption time, uplink, downlink, and jitter	Quality up 500 km/h	Quality up to 350km/h
Connection density	Ability to support data delivery within a certain time in a space-constrained location	Over 100,000 connections per square kilometer	2,000 connections per square kilometer

Note: All data points are approximations, given the existence of many different standard specifications.
Source: The CIO's Guide To 5G Connectivity And Strategy Forrester report

5G is in the early deployment stage due to significant telco infrastructure investments and new devices
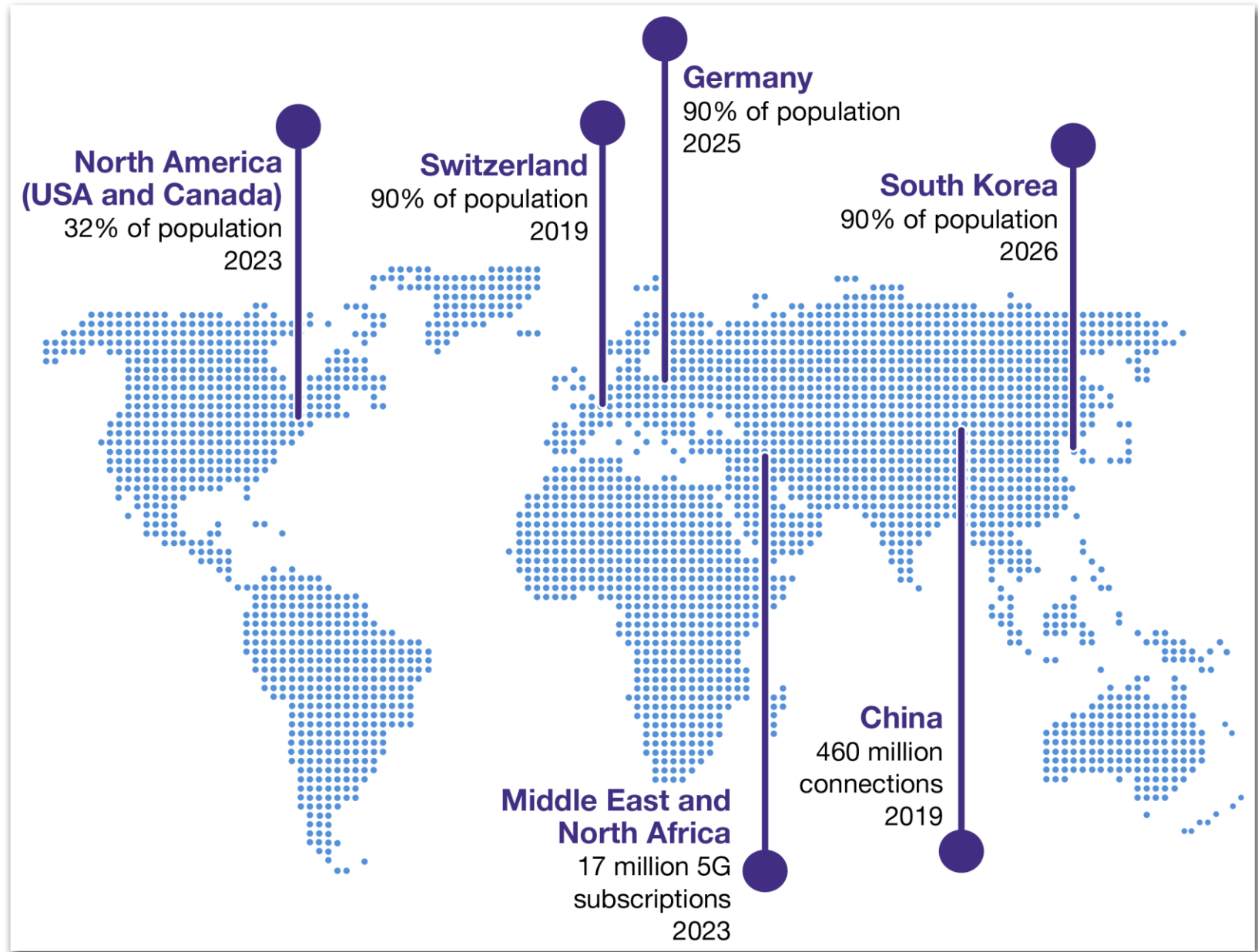
5G networks are emerging

- 5G network deployment occurs on a block-by-block basis.

- Financial returns for telcos and government investments to jump-start deployment will impact rollout timelines.

- Seamless network availability will take many years in most regions.

5G device availability is limited

- Mobile devices and sensors must use new 5G technology.

- Device and chipset availability trails standards and network deployment.

- Devices are relatively rare and costly.

Global 5G coverage and service subscriptions are projected to support 29% (2.9 billion) of all mobile subscriptions by 2025

North America (USA and Canada)
32% of population
2023

Switzerland
90% of population
2019

Germany
90% of population
2025

South Korea
90% of population
2026

Middle East and North Africa
17 million 5G subscriptions
2023

China
460 million connections
2019

Evaluate private 5G network availability and benefits to protect proprietary data and enable critical applications

Private 5G network characteristics

- Dedicated LAN with unified connectivity, optimized services, and secure communication

- Focused on a specific geographic space (e.g., factory, hospital, logistics center, or stadium)

- Designed for selected users, employees, or machines (not for public access)

- Isolates business critical and competitive data from the public network

- Gives network owner control over security, how various resources are utilized, and which applications have priority

Availability varies by region

- **UK:** Ofcom licensing covers local access to the 3.8 GHz to 4.2 GHz band and 1800 MHz and 2300 MHz shared spectrum licensed to mobile operators but is not used or planned to be used for three years.

- **Germany:** Federal Network Agency (BNA) allocated 100MHz of spectrum in the 3.7 to 3.8 GHz band for industrial deployments and accepts applications for 10-year local licenses.

- **US:** The Federal Communications Commission (FCC) opened up the 3.5 GHz band, known as the Citizens Broadband Radio Service (CBRS), for commercial use.

Source: Non-Public 5G Networks Will Be A Critical Building Block Of Your Enterprise
Forrester report

Deployment comparisons for public 5G versus private 5G networks

	Public 5G network	Private unlicensed 5G spectrum	Network slicing of 5G network	Private licensed 5G spectrum
Likely network operators	Telco	Business; equipment vendor	Telco; equipment vendor	Business; managed by vendor or telco
Reliability	Medium	Low	Medium	High
Data management	Data leaves the premises	Data partially leaves the premises	Data partially leaves the premises	Data stays inside the premises
Coverage area	Premises and beyond	Premises	Premises and beyond	Premises
Cyber security and privacy level	Medium	Low	Medium	High
Examples of use cases	• Wireless connectivity for sensors and IoT devices • Remote access and maintenance	• Wireless connectivity for sensors and IoT devices • Remote access and maintenance	• Automated guided vehicles • Remote machine access	• Industrial mobile robots • Industrial safety • Virtual reality

Source: Non-Public 5G Networks Will Be A Critical Building Block Of Your Enterprise Forrester report

Address security vulnerabilities related to 5G network deployments

- Gaps in network equipment interoperability
  - Ensure equipment interoperability from different manufacturers and consistent security controls (e.g., authorization and authentication controls, IoT device security, encryption, anomaly detection, deter backdoor access to call details).

- Decentralized SDN webs' lack of centralized points of inspection
  - Upskill networking professionals to manage virtualized networks, work with network function virtualization (NFV), and software-defined networking (SDN) deployments.

- Edge computing and millions of IoT endpoints expand attack surface.
  - Nefarious actors can take over edge devices to form a botnet, which performs distributed denial of service (DDoS) attacks to paralyze networks.

Source: [Securing Private 5G At The Edge: Europe Edition](#) Forrester report

Evaluate your 5G strategy using three key areas

5G planning

Business strategy

- Plan at the use case level
- Evaluate telco and device partnerships
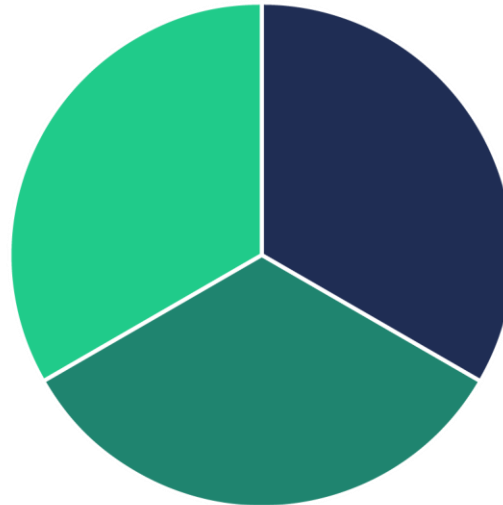
Technology

- Assess connectivity needs
- Identify IoT and edge computing requirements

Operations

- Enhance workplace collaboration
- Enable operational processes

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Edge computing: our definition

Endpoint and endpoint-enablement resources that manage
and analyze localized data and empower near-real-time
insights, engagement, and automation within physical
proximity to endpoint devices and customers.

They include edge management and intelligence software that
runs on or near endpoint devices (IoT, mobile, etc.) so the
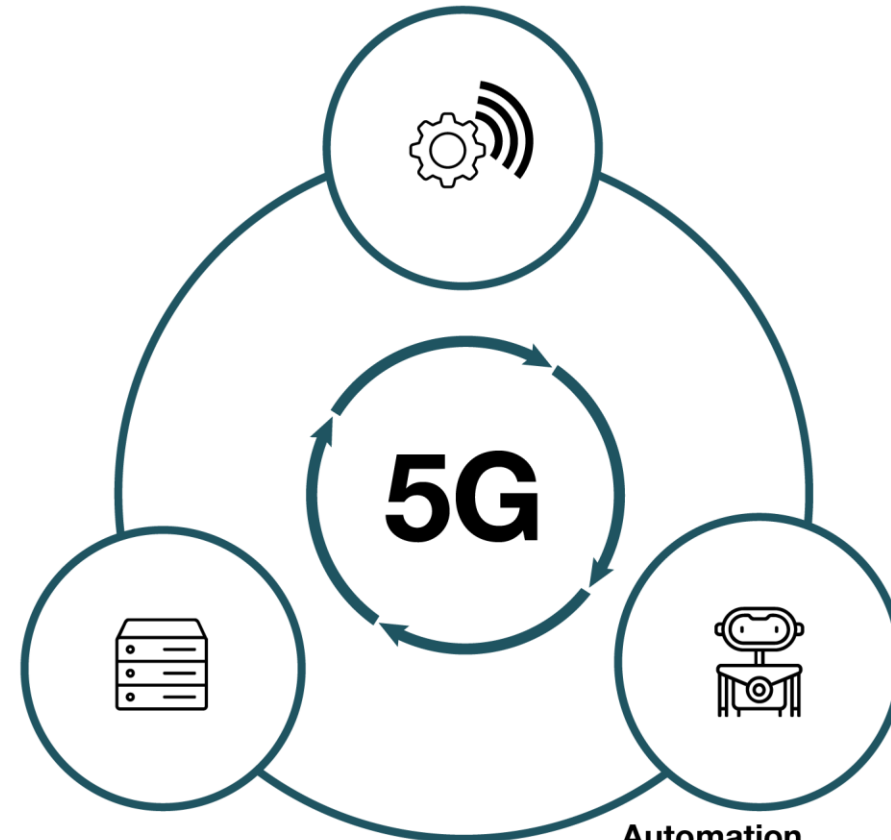actions can be completed immediately.

Source: A Decoder Ring For Edge Computing Forrester report

5G networks extend IoT, automation, and edge computing use cases

IoT
5G infrastructure can connect tens of millions of wireless devices and enable machine-to-machine (M2M) communication links in the internet of things.
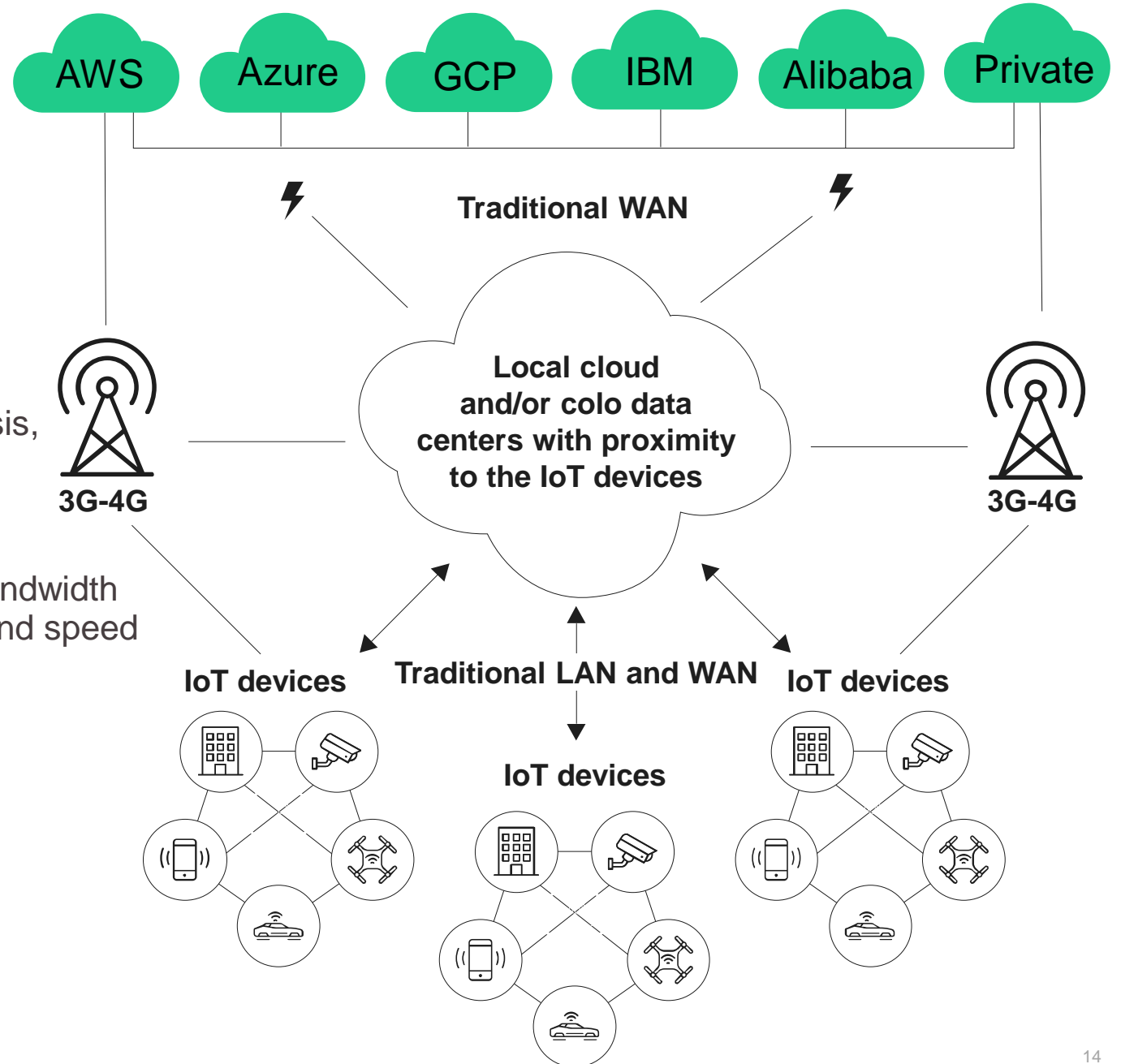

Edge
5G enables data processing close to the connected device, using ultra-low latency and ultra-high bandwidth, and extends the breadth and variety of supported edge computing use cases.

Automation
5G enables efficient deployment of key automation use cases (e.g., factory robots, automated guided vehicles, machine vision quality, and smart building monitoring).

Source: January 30, 2020, "5G Part Three: IoT, Edge Computing, And Network" Webinar (https://www.forrester.com/webinar/5G+Part+Three+IoT+Edge+Computing+And+Network/-/E-WEB29827)

IoT prior to 5G and edge

Seconds to minutes for delivery, analysis, and insights

AWS · Azure · GCP · IBM · Alibaba · Private

Traditional WAN

Milliseconds to seconds for delivery, analysis, and insights

3G-4G

Local cloud and/or colo data centers with proximity to the IoT devices

3G-4G

For real-time insights: Smart IoT devices were required — rare and significantly more expensive.

Smart machines and robots
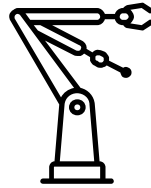
Limited bandwidth capacity and speed

IoT devices

Traditional LAN and WAN

IoT devices

IoT devices

Note: Adapted from IBM graphic
Source: A Decoder Ring For Edge Computing Forrester report

IoT endpoints

Smart. Contains storage, compute, and intelligence equipment for real-time analysis and actions based on its local data collected

Connected. Sensor-equipped devices, such as smart lights, that pass their insights to aggregators via networks externally

Dumb. Devices with sensors and connectivity but limited storage and compute

Edge compute

Equipment specifically designed and packaged for the purpose of near-real-time multiendpoint device content aggregation, analysis, and action enablement.

Deployed at the endpoint on edge networks; deployed in edge gateways nearby or in the cloud.

Public and private cloud backends provide broader but slower data aggregation.

Components:

Edge compute infrastructure
Management software, storage, CPU, GPU, and bidirectional networking:
1. to end devices
2. to clouds/DCs

Edge intelligence fabrics

Business logic. Execute automated actions based on analytics, data flow, and user interaction.

Analytics. Manage and govern rules-based, statistical, and machine learning model to action execution.

Data flow and security. Manage edge data, flow, and data security policy enforcement.

Edge networking. Mesh networks, local Wi-Fi, peer-to-peer networking (e.g., Bluetooth); in many cases, devices, and, in some cases, full edge systems' networks, may be **air gapped** — not permanently networked, for security reasons

Source: A Decoder Ring For Edge Computing Forrester report

5G will drive momentum for IoT use cases in many industries

Vertical market	Examples of 5G use cases	Important requirements
Automotive	• Self-driving cars • Vehicle-to-infrastructure communication • Vehicle infotainment applications	• Long-range transmission • High bandwidth • Low latency • Quality of service
Industrial manufacturing	• Mission-critical factory automation • Remote supervision and control of machines • Manufacturing process automation	• Low latency • Long battery life • Quality of service
Healthcare	• Remote robotic telesurgery • Remote patient monitoring • Medical treatment aided by augmented reality	• Long-range transmission • Low latency • Quality of service
Media and entertainment	• Ultra-high-definition video (4K/8K) • Immersive media applications • Augmented reality/virtual reality gaming	• High bandwidth • Low latency • Quality of service
Smart cities and utilities	• Smart buildings • Smart transportation • Smart meter monitoring	• Bandwidth consumption, depending on use case • Long battery life

Source: Cut Through The Hype To Assess Your Need For 5G-Enabled IoT Use Cases Forrester report

5G powers several physical automation technologies

Technology	Use Cases	Vendor Examples
Automated vehicles	Vehicles capable of autonomous or near-autonomous operations on land, water or in the air. Use cases include: trucking/logistics, cargo shipping, monitoring pipelines, unmanned mining vehicles.	ABB, Argo AI, Caterpillar, General Atomics, Here, Mobile Eye, Starsky Robotics
Delivery robots	Physical robots (e.g. drones) that move physical goods from place to place. This could include inside a factory or hospital or externally (e.g. delivery to a customer).	Aethon TUG, Amazon Scout, Kiwi Robots, Marble Robots, Matternet, Starship Technologies
Field service robots	Physical machines that inspect, carry, and fix machinery. Automated analysis of workspaces can cut costs and improve efficiency.	Envirosight, GE Inspection Robotics, Intel Commercial Drones, QuadSATdrones
Industrial robots	Physical machines execute complex repetitive tasks in manufacturing environments. This technology segment includes industrial cobotsthat work safely alongside humans.	Comau, Fanuc, Kawasaki Heavy Industries, KukaRobotics
Inspection and surveillance robots	Physical machines that use different computer vision-powered robotic systems to conduct visual examination and task monitoring. Use cases include: asset examination for environmental monitoring.	Clobotics, Deep Trekker, GekoRobotics, GE Inspection Robotics, Honeybee Robotics, Invert Robotics, Sarcos, SMP Robotics
Retail and warehouse robots	Physical machines that move pallets of goods, monitor or stock shelves, and pick/pack. Capabilities run through structured, semi-structured, and unstructured environments.	Aethon TUG, Amazon Robotics, Fetch Robotics, Ocado Smart Platform for Grocery

Source: Advance Your Physical Robotics RQ With Forrester's Automation Framework Forrester report

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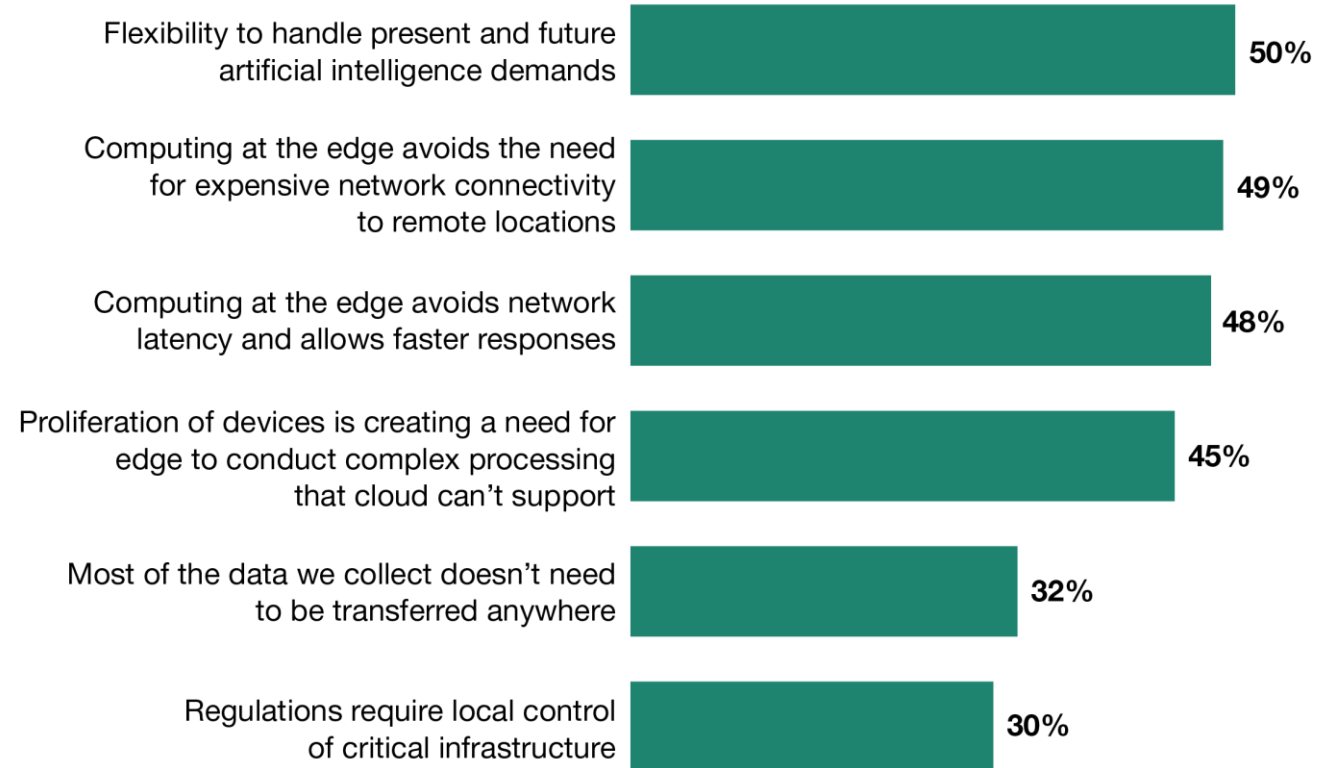# Edge computing is helping solve previously intractable problems

Employ real-time AI across the physical/digital divide to solve previously unresolved business problems.

- **Drive better customer experiences and higher profits.** Customer experience improves as shoppers always find what they need, and store margins improve with greatly improved analytics and planning.

- **Diagnose and treat diseases with precision.** Scanning a cardiology patient's heart with an IoT-enabled robot and using AI gives the physicians scan details and helps them make sure the right planes are captured.

- **Drive increased production and revenue.** Applying machine learning algorithms to IoT insights helps human employees make better, faster decisions and then act on physical-world problems.

Source: The Revenge Of The Atoms Forrester report

Overall edge computing benefits include AI, processing power, low latency, and reduced costs

"Which of the following do you believe are the biggest benefits to your organization's using edge computing?"

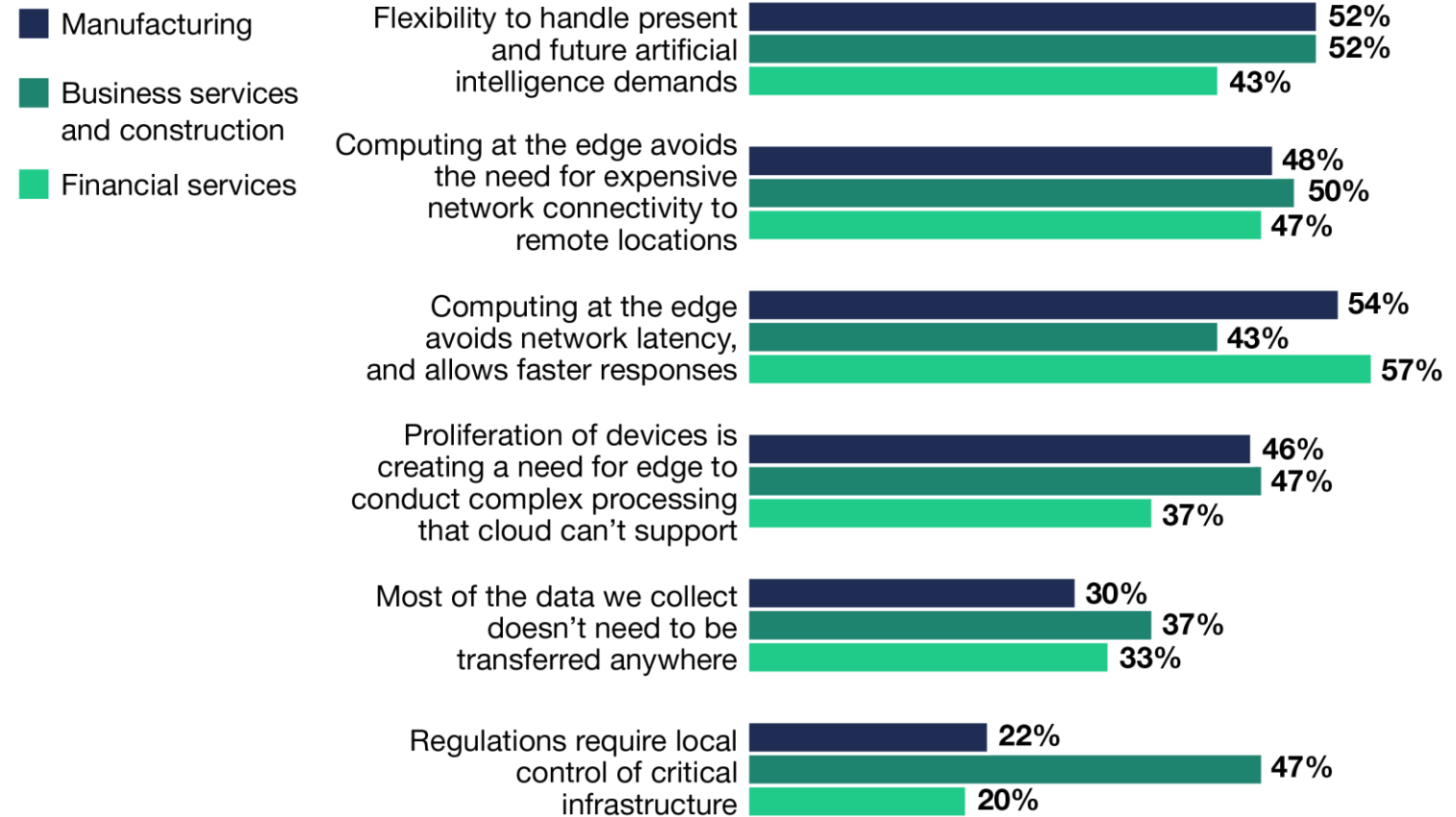| Benefit	Percentage
Flexibility to handle present and future artificial intelligence demands	50%
Computing at the edge avoids the need for expensive network connectivity to remote locations	49%
Computing at the edge avoids network latency and allows faster responses	48%
Proliferation of devices is creating a need for edge to conduct complex processing that cloud can't support	45%
Most of the data we collect doesn't need to be transferred anywhere	32%
Regulations require local control of critical infrastructure	30%

Note: Not all response options are shown.
Base: 207 global mobility decision makers whose firm is implementing edge computing (1,000+ employees); Source: Forrester Analytics Global Business Technographics® Mobility Survey, 2019

Edge computing benefits vary by industry

"Which of the following do you believe are the biggest benefits to your organization's using edge computing?"

- ■ Manufacturing
- ■ Business services and construction
- ■ Financial services

Flexibility to handle present and future artificial intelligence demands
- 52%
- 52%
- 43%

Computing at the edge avoids the need for expensive network connectivity to remote locations
- 48%
- 50%
- 47%

Computing at the edge avoids network latency, and allows faster responses
- 54%
- 43%
- 57%

Proliferation of devices is creating a need for edge to conduct complex processing that cloud can't support
- 46%
- 47%
- 37%

Most of the data we collect doesn't need to be transferred anywhere
- 30%
- 37%
- 33%

Regulations require local control of critical infrastructure
- 22%
- 47%
- 20%

Note: Not all answer options are shown.
Base: 30 to 63 global mobility decision makers whose firm is implementing edge computing (1,000+ employees); Source: Forrester Analytics Global Business Technographics® Mobility Survey, 2019
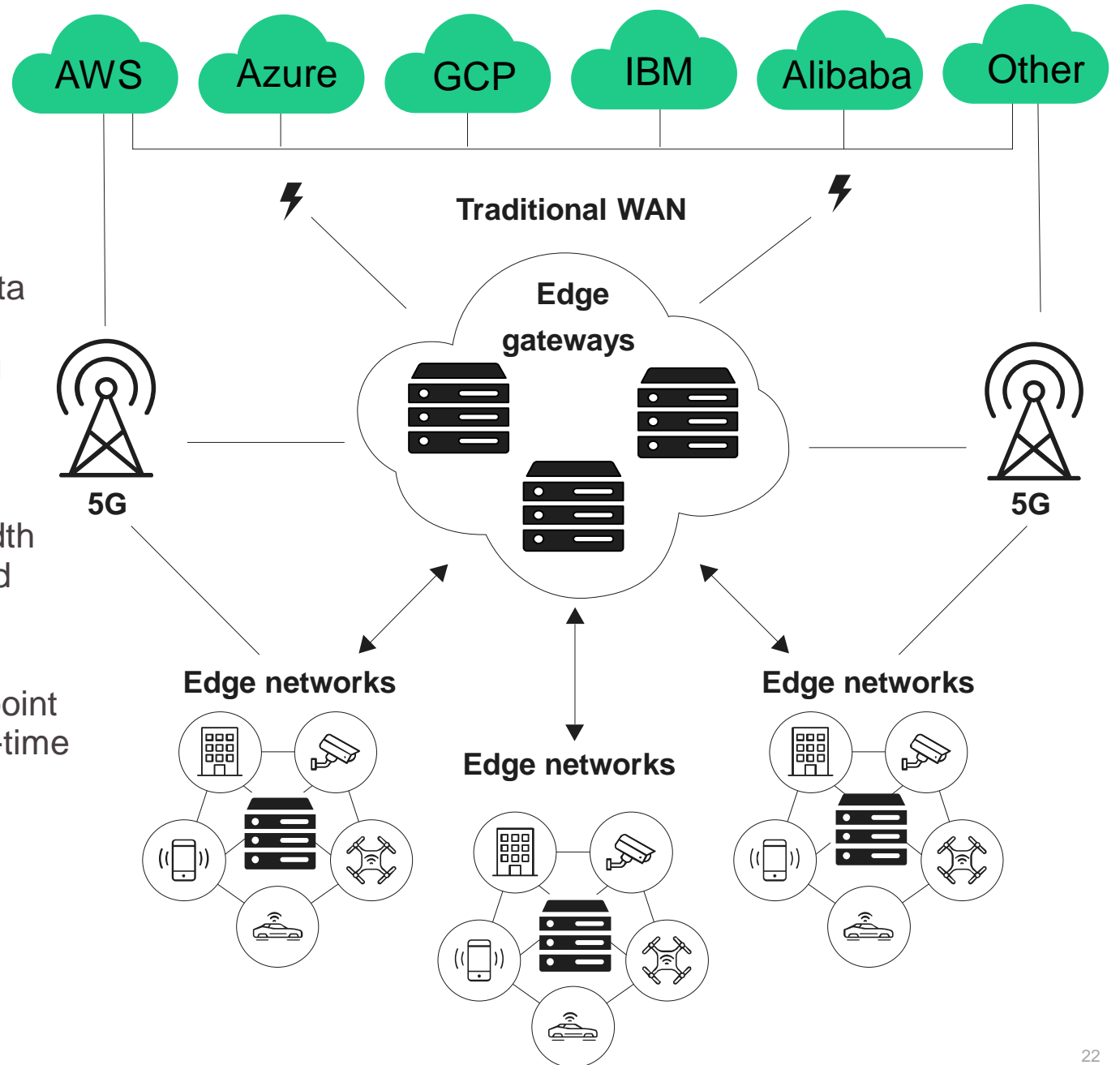
Edge and 5G impact

5G accelerates bandwidth and speed for traditional analysis.

Local cloud and colo data centers serve as edge gateways, now enabling near-real-time analysis.

Enhanced bandwidth capacity and speed

 = Edge compute units

Edge compute in endpoint networks enables real-time analysis and insights.

AWS **Azure** **GCP** **IBM** **Alibaba** **Other**

Traditional WAN

Edge gateways

5G

5G

Edge networks

Edge networks

Edge networks

Note: Adapted from IBM graphic
Source: A Decoder Ring For Edge Computing Forrester report

Edge computing benefits

5G enhances some but not all . . .

Latency reduction
Onsite edge computing enables real-time analysis. 5G networks enable ultralow latency (<20ms) data delivery to edge gateways. So long as the gateways are connected to centralized data and business logic, AI-driven analysis and results return much faster.

Cost reduction
Processing power enabled by 5G networks reduces costs associated with network round tripping, lowering centralized storage, and compute costs.

Security/ compliance
Localized network processing, system, and controls require sending less data back to the cloud, enabling more control over localized security and regulatory compliance and avoiding cloud eGress charges.

Innovation
Accelerate innovation by exploiting insights-distributed high-performance applications built on 5G-enabled connected things, processes, and people. Enable new business model and revenue opportunities.

Scale
Scale automation and engagement use cases across a fragmented array of 5G connected devices, and an increasing number of connected devices in various locations, while minimizing day 2 operations costs.

Resiliency
Build highly distributed systems supported by redundant converged subclouds that continue to operate when individual components and communication points fail.

Source: A Decoder Ring For Edge Computing Forrester report

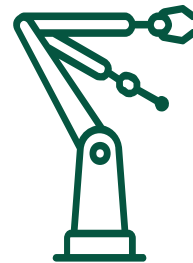# . . . that translate into three business value deliveries

Human engagement (B2C, B2E, and P2P)

Putting resources closer to people to drive up their real-time engagement

Business engagement (B2B)

Build and empower B2B apps closer to where your ecosystem partners are located and need real-time value
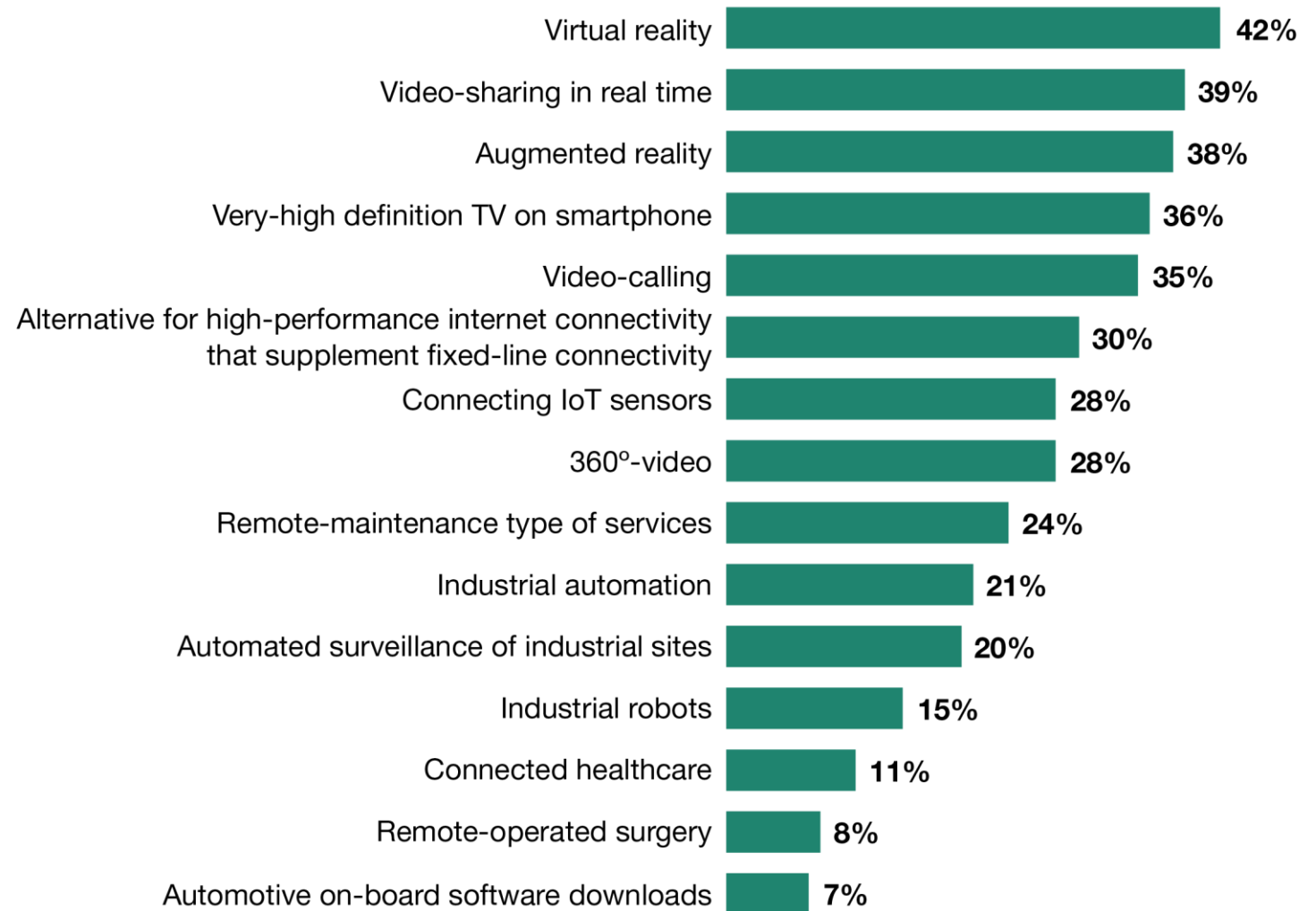
Interdevice automation (IoT and M2M)

Being closer to autonomous things and driving near-real-time insights and actions

Source: A Decoder Ring For Edge Computing Forrester report

Key 5G-enabled applications span various IoT, automation, and edge use cases

"Which of the following will be the use cases that your firm is most likely to use 5G for?"

Use case	%
Virtual reality	42%
Video-sharing in real time	39%
Augmented reality	38%
Very-high definition TV on smartphone	36%
Video-calling	35%
Alternative for high-performance internet connectivity that supplement fixed-line connectivity	30%
Connecting IoT sensors	28%
360°-video	28%
Remote-maintenance type of services	24%
Industrial automation	21%
Automated surveillance of industrial sites	20%
Industrial robots	15%
Connected healthcare	11%
Remote-operated surgery	8%
Automotive on-board software downloads	7%

Note: Not all response options are shown.
Base: 2,077 global mobility decision makers who are planning to build or leverage 5G enterprise network infrastructure; Source: Forrester Analytics Global Business Technographics® Mobility Survey, 2019

Research insights agenda

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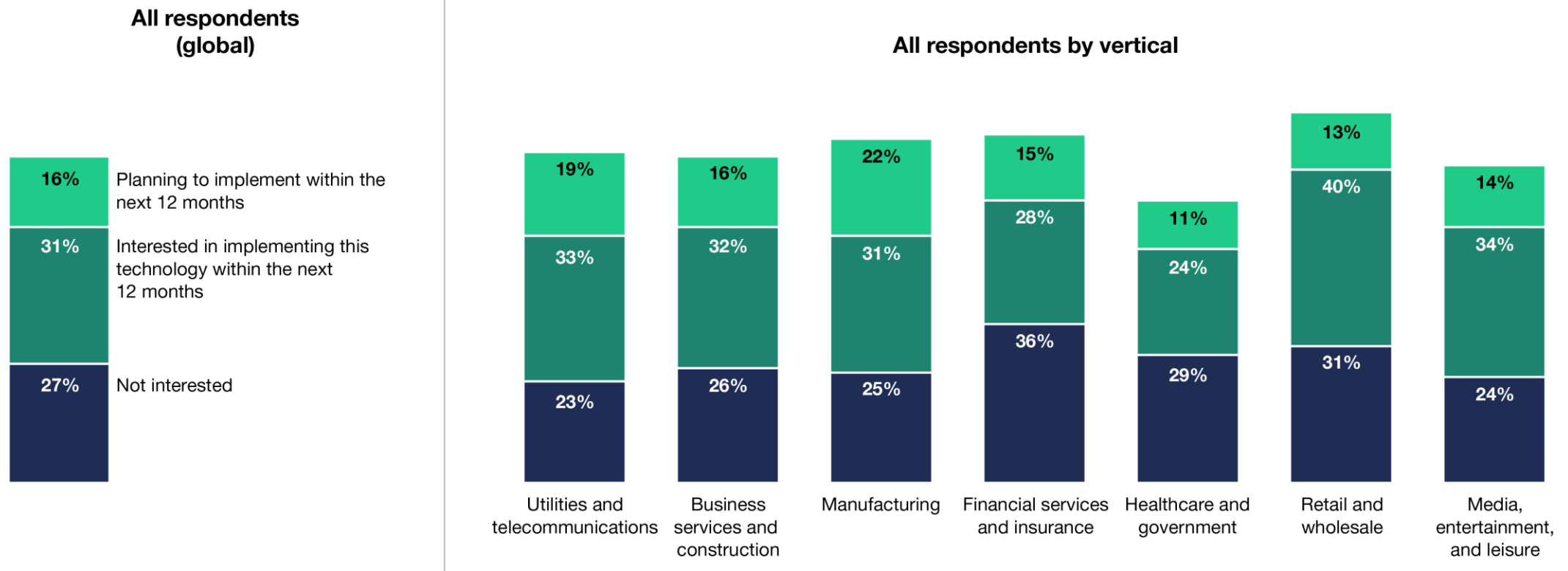
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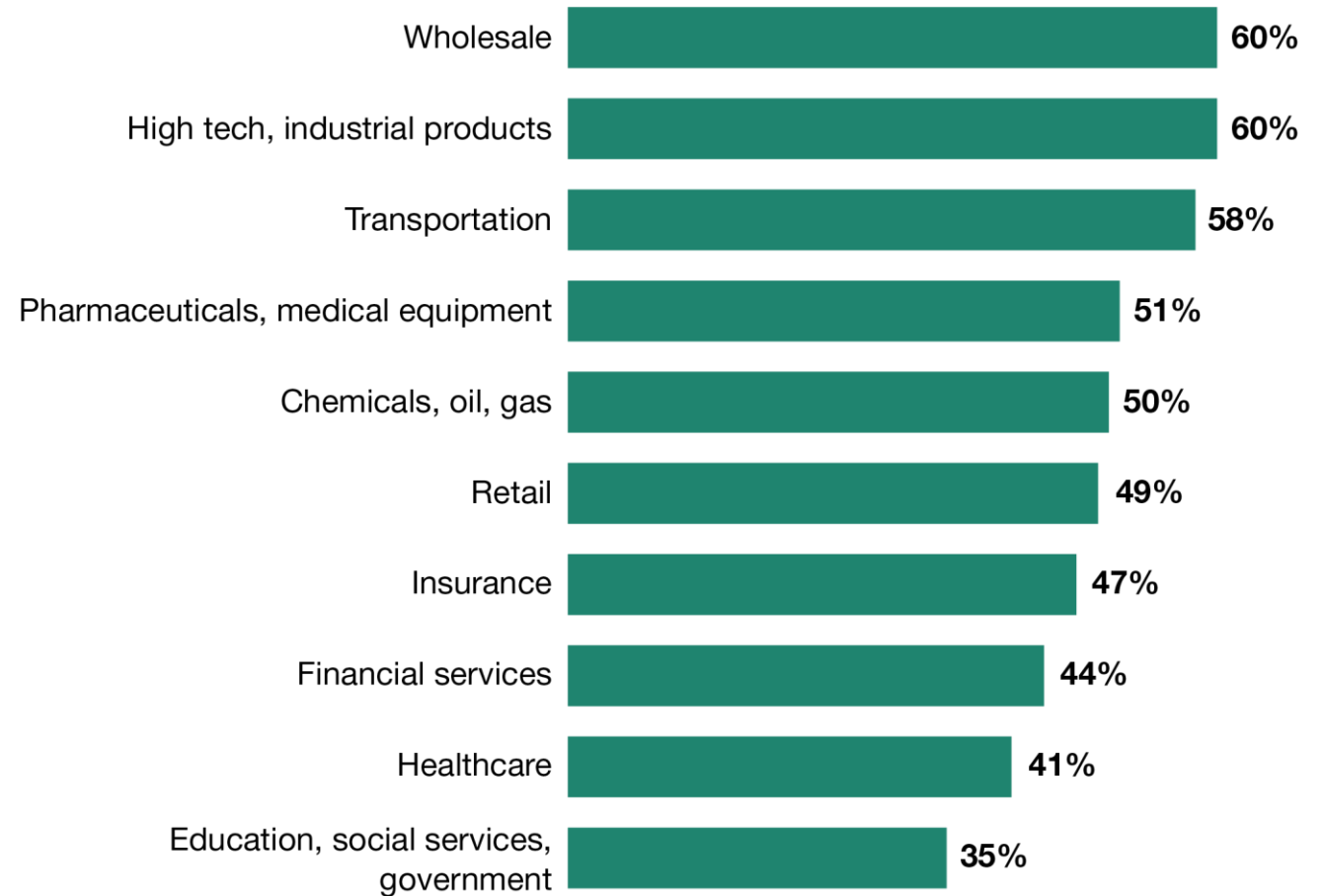# Vertical market planned edge compute adoption in the year: 2020

All respondents (global)

16%	Planning to implement within the next 12 months
31%	Interested in implementing this technology within the next 12 months
27%	Not interested

All respondents by vertical

	Utilities and telecommunications	Business services and construction	Manufacturing	Financial services and insurance	Healthcare and government	Retail and wholesale	Media, entertainment, and leisure
Planning	19%	16%	22%	15%	11%	13%	14%
Interested	33%	32%	31%	28%	24%	40%	34%
Not interested	23%	26%	25%	36%	29%	31%	24%

Note: Not all response options are shown. We excluded respondents who did not express a knowledge of edge computing (either what it is or what their companies are doing in this area).
Base: 3,520 global mobility decision makers and 96 to 1,038 global mobility decision makers (base sizes vary by industry); Source: Forrester Analytics Global Business Technographics® Mobility Survey, 2019

5G network investments are on the roadmap for stakeholders in many industries

"What are your firm's plans to adopt 5G network technologies?"

Implementing/implemented + expanding/upgrading implementation)

Industry	%
Wholesale	60%
High tech, industrial products	60%
Transportation	58%
Pharmaceuticals, medical equipment	51%
Chemicals, oil, gas	50%
Retail	49%
Insurance	47%
Financial services	44%
Healthcare	41%
Education, social services, government	35%

Base: 30 to 140 global telecommunications decision makers who are significantly involved in wired/landline data technology across industries; Source: Forrester Analytics Global Business Technographics® Networks And Telecommunications Survey, 2019

5G and edge enable smart factory applications

- Private 5G networks primarily used to support many factory use cases

- Remote quality assurance with 4K high-resolution cameras and image analytics

- Automated vehicle routing to specified factory locations

- Real-time location and status of robotics

- Predictive maintenance and monitoring of machines

5G and edge value delivery in manufacturing

Business problem

5G in the industrial manufacturing context offers opportunities beyond factory automation, also covering process automation, human-machine interfaces, logistics, warehousing, monitoring, and maintenance. Manufacturers see the value to more accurately predict equipment failures but struggle to scale predictive analytics to every asset in their manufacturing facilities.

Industries
Industrial manufacturing
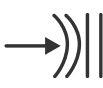
Human engagement (B2C, B2E, and P2P)	✓ Improve employee safety and empowerment
Interdevice automation (M2M/IoT)	✓ Real-time insight from cameras and sensors train predictive models efficiently
Business engagement (B2B)	✓ Exchange data and services with component and plant equipment makers

Latency	Faster, proactive predictive maintenance, equipment failure, and alert response
Cost	More local processing at the sensor and device level reduces network costs.
Security	High-risk plant systems and competitive operational processes leverage improved local security.
Intelligence	Improve worker safety, enhance operational processes, and increase production uptime at reduced cost.
Scale	Can replicate across multiple factories, warehouses, operational processes, and distribution channels
Resiliency	Local compute and networks can cache critical data for recovery.

5G and edge computing value

Private 5G networks in the manufacturing environment capture a holistic view of connected assets throughout plant operations by blending insights from cameras and robots, connected machinery, and equipment. Assess overall operational health and production quality by aggregating data across equipment while keeping critical operations up and workers safe.
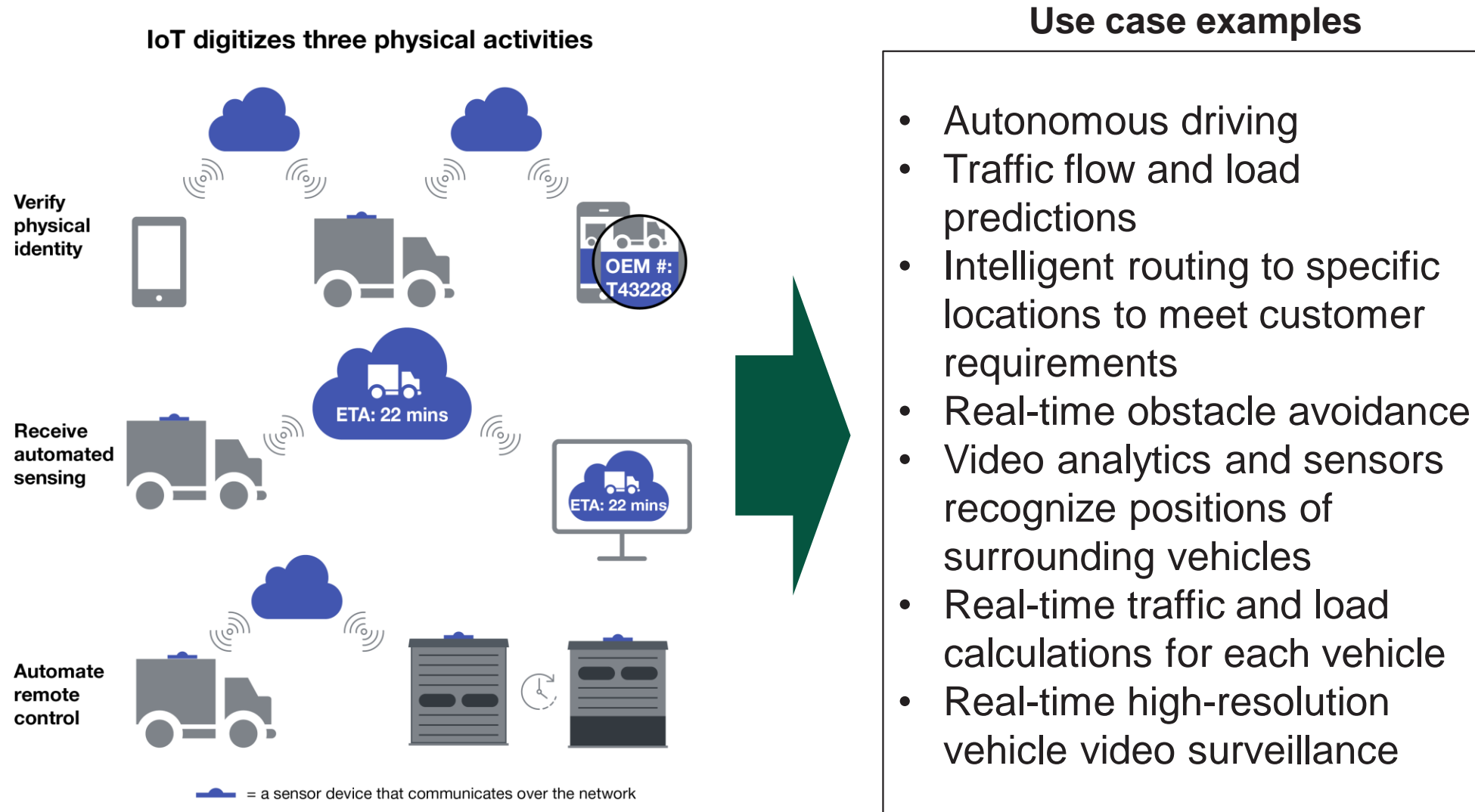
5G and edge technologies

- Private 5G networks provide enhanced privacy, higher data security, better compliance, and better cellular network performance for user groups, applications or assets.
- Computer vision accelerates edge machine learning using cameras, ambient, and equipment sensors.
- Edge gateway servers connect operational technologies and networks to enterprise data and reporting.
- SD-WAN and SDN create network fabrics supporting local compute and asset connections.
- Edge intelligence fabric software automates event-driven, near-real-time action.

Source: A Decoder Ring For Edge Computing
Forrester report

Transportation in route empowerment: 5G and edge solutions enable multivehicle near-real-time aggregation and action enablement for safety and experience optimization

IoT digitizes three physical activities

Verify physical identity

OEM #: T43228

Receive automated sensing

ETA: 22 mins

ETA: 22 mins

Automate remote control

= a sensor device that communicates over the network

Use case examples

- Autonomous driving
- Traffic flow and load predictions
- Intelligent routing to specific locations to meet customer requirements
- Real-time obstacle avoidance
- Video analytics and sensors recognize positions of surrounding vehicles
- Real-time traffic and load calculations for each vehicle
- Real-time high-resolution vehicle video surveillance

Source: A Decoder Ring For Edge Computing Forrester report and Use Three IoT Scenarios To Untangle Your IoT Strategies Forrester report

5G and edge value delivery in transportation

Industries
Transportation, telcos, and government

Human engagement (B2C, B2E, and P2P)
- ✓ Improve customer and employee safety and empowerment.
- ✓ Device robotics

Interdevice automation (M2M/IoT)
- ✓ Cameras, lights, vehicle subcomponents, dashboard, etc.
- ✓ Smart vehicle and port facility hubs

Business engagement (B2B)
- ✓ Telcos, governments, transportation makers, and services

Source: [A Decoder Ring For Edge Computing](#) Forrester report

Business problem

5G powered transportation use cases include connected vehicles and autonomous cars. In addition, transportation makers are installing more and more sensors across components within their vehicles, on the roads, and in transportation stations (such as airports) for the purposes of ensuring vehicle safely, optimal efficiency, and customer experience gains. Aggregation and empowerment drives edge ecosystems opportunity for telcos, smart product makers, vehicle retailers, and services.

Latency	5G enables the low latency necessary for safe operations. Edge solutions capture real-time insight from vehicle sensors.
Cost	Data is not stored in the cloud.
Security	Concerns related to data privacy and cybersecurity are key challenges in the transportation sector. Raw data does not leave the confines of vehicles or neighborhoods.
Intelligence	Vehicle makers' losses from stolen vehicles are reduced.
Scale	5G network coverage limitations reduce scale to specific routes or industrial sites.
Resiliency	5G does not depend on cable IP for some functions.

5G and edge computing value

Extremely low latency of 5G networks powers autonomous vehicle operations. Edge processing optimizes vehicle functions using component sensors and cameras. Pass results to vehicle hub and aggregate results across multiple vehicles to an edge gateway. Identify security risk situations and route optimization results to pass back to the vehicles and drivers. Pass security and injury results and vehicle tracking information to the police. Telcos track by connecting urban cameras to edge apps running on mobile base stations.

5G and edge technologies

- 5G enables ultra low latency and high reliability required for safe vehicle operations.
- Computer vision does edge machine learning on smart cameras and vehicle hubs.
- Vehicle edge gateway engines coordinate responses with police and notify drivers of issues and actions to take.
- Transportation solutions use telco mobile edge computing to track vehicles with urban cameras.

Healthcare firms use private 5G and edge to capture insight from connected facilities, equipment, and patient wearables

- Rush University Medical Center in Chicago is deploying AT&T's 5G network and multiaccess edge computing (MEC) solution at its campus.

- Rush's edge computing solution hosts an instance of AT&T's core network and multiaccess edge computing services on site to eliminate latency, deliver critical applications, ensure data security, and improve the patient experience.

- Additional 5G and edge healthcare use cases include:
    - Simplifying real-time assessments of patient status.
    - Assisting nurses and doctors with IoT and patient mobile asset and equipment insights.
    - Running purpose-built edge applications to inform medical staff of critical insights and patent's past.
    - Evaluating and processing high-resolution medical images.

Source: A Decoder Ring For Edge Computing Forrester report

5G and edge value delivery in healthcare

Industries
Healthcare, insurance and care equipment, and medication

Human engagement (B2C, B2E, and P2P)	✓ Improve patient safety and empowerment.
Interdevice automation (M2M/IoT)	✓ Visual data from cameras, MRIs, etc., used to train predictive models efficiently
Business engagement (B2B)	✓ Exchange data and services with medical staff and healthcare digital twins

Business problem

The healthcare industry is transforming. 5G and edge technologies power the expanding array of connected devices, wearables and operational processes throughout the healthcare system. Wider adoption of applications is based on wearables. Healthcare providers see the value in more accurately predicting patient status and needs but struggle to deliver predictive real-time analytics to empower local staff more effectively.

Latency	Faster failure time prediction and alert response
Cost	5G local processing reduces network costs.
Security	Proprietary patient information and high-risk healthcare systems have improved local security.
Intelligence	Improve patient and medical staff safety and production uptime at reduced cost
Scale	Can replicate across multiple hospitals, distribution centers, healthcare equipment and facilities
Resiliency	Local compute and networks can cache critical data for recovery.

5G and edge computing value

Capture a holistic view of on-site patient symptoms and care by blending insights from cameras mobile devices and facility equipment and other sensors. Evaluate asset overall operational health by aggregating data across equipment while still keeping patient care up and workers safe.

5G and edge technologies

- Medical institutions are collaborating with telecom companies to seek breakthroughs in telemedicine enabled by 5G.
- Computer vision accelerates edge machine learning using cameras, ambient, and equipment sensors.
- Edge gateway servers connect operational technologies and networks to enterprise data and reporting.
- SD-WAN and Wi-Fi create network fabrics support local compute and connection to facility assets.
- Edge intelligence fabric software automates event-driven, near-real-time action.

Source: A Decoder Ring For Edge Computing Forrester report

Experience spaces — stadiums: 5G and edge solutions empower spectators, athletes, and fans watching from home

- Camp Nou, a covered stadium for approximately 105,000 spectators, was the first stadium in Europe with internal 5G coverage.

- The stadium field uses Telefónica's 5G commercial band and Ericsson's 3GPP network.

- Wireless 360⁰ cameras connected by a 5G network provide home viewers with immersive sports content.

- Spectators can use virtual reality (VR) glasses to watch the match from the directors' box, behind a goal, by the benches, or from other viewpoints in the stadium.

- The 5G network can be used to provide virtual stadium tours.

5G and edge value delivery in experience spaces: stadiums

Industries
Media and entertainment, telco, and retail

Human engagement (B2C, B2E, and P2P)
- ✓ Fan experience augmentation
- ✓ Player training
- ✓ Employee empowerment

Interdevice automation (M2M/IoT)
- ✓ Communications equipment
- ✓ Concessions
- ✓ A/C
- ✓ Field sensors

Business engagement (B2B)
- ✓ Teams
- ✓ Sports leagues
- ✓ Broadcast networks
- ✓ Various vendors
- ✓ Parking
- ✓ Retail marketing

Source: A Decoder Ring For Edge Computing Forrester report

Business problem

Sports venues are unique among experience spaces. For conventional sports venues, 5G can enable uninterrupted streaming of events to a wide audience and leverage virtual reality to enable new remote participation experiences. The number of fans, their expectation for near-real-time digitally augmented experiences, and the number of companies that must work together to create the space and monetize it all create integration and real-time data challenges that can't be solved without edge computing.

Latency	Real-time insight integrated sensors and cameras; 5G technology streamlines uploading of video.
Cost	Reduce network costs; wireless 360 cameras don't need wired communications.
Security	Improve physical security for large crowds; protect fan privacy.
Intelligence	Support new digital value innovations for fans and B2B.
Scale	Near-real-time experiences for tens of thousands of fans in the stadium or at home using immersive video content
Resiliency	Internet and cellular connectivity failures don't jeopardize business revenue.

5G and edge computing value

Offload image processing and AI workloads to local compute clusters, optimize network traffic and mobile app responsiveness by smart routers and multiaccess edge clouds (MEC), and enable device-to-device automation.

5G and edge technologies

- 5G low latency and edge computing allow flexibility when placing 360 cameras.
- Computer vision does edge machine learning on cameras and edge empowerment resources (local computer clusters, gateways, smart routers and nearby MEC resources).
- CDN edge services enable near-real-time fan, player, and employee experiences.
- Edge intelligence fabrics distribute business logic across smart devices and edge empowerment infrastructure.
- Colocation network fabrics offload heavy processing at localized data centers.

5G and edge promise to transform retail on several levels

- 5G-enhanced mobile broadband enables virtual and remote sales support, providing customers with product information throughout the sales lifecycle.

- Edge computing of myriads of connected IoT sensors enable inventory, supply chain, and track-and-trace solutions and boost transparency and efficiency.

- 5G and edge compute enable lower-latency, data-driven customer insights; virtual and augmented reality (VR and AR) services; cashierless checkouts; smart screens; and mobile cloud services.

- Other 5G-enabled retail applications include cashless and cardless shopping using biometric authentication.
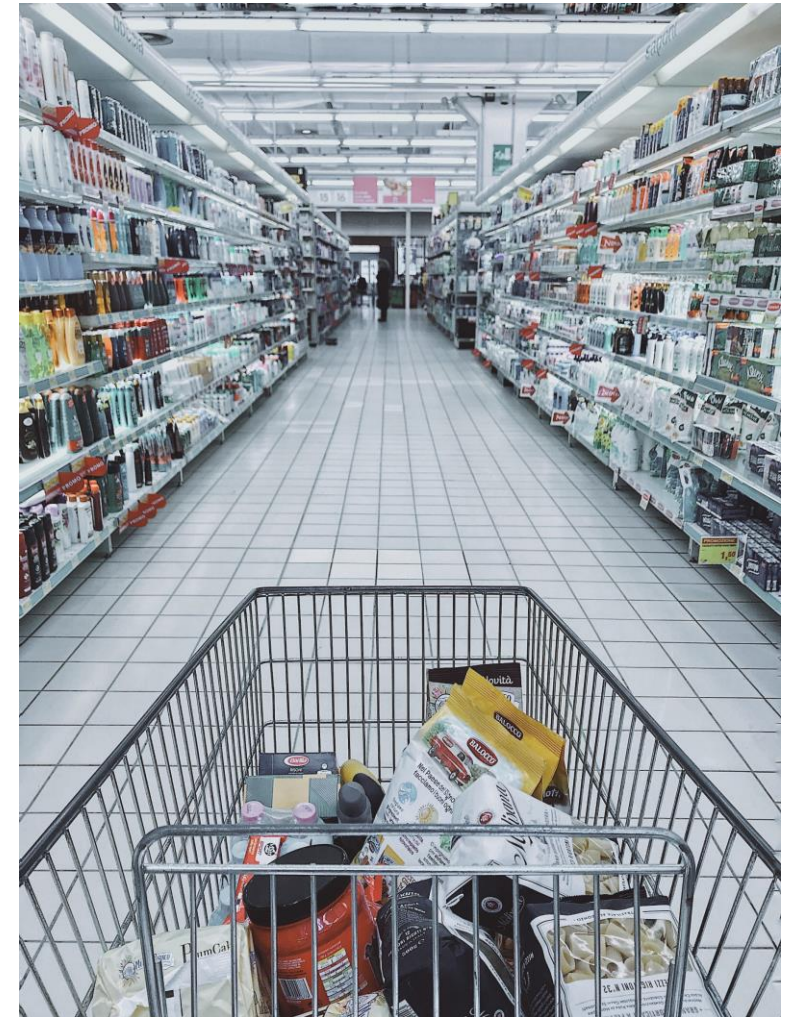
Source: A Decoder Ring For Edge Computing Forrester report and The CIO's Guide To 5G In The Retail Sector Forrester report

5G and edge enable trust in financial services

- Video chat consultations

- Mobile pop-up branch enablement

- ATM placement flexibility

- Leverage ultra low latency necessary for AI-powered fraud detection

- Example: Banco Santander, Telefónica, and ZTE deploy 5G banking in Spain.

Land, water, and building infrastructure: nonresidential, remote business and government run locations involve land, water features, and permanent infrastructure

Land, water, and building infrastructure categories

- **Waterways:** lakes, ocean fronts, and rivers

- **Infrastructure:** bridges and tunnels

- **Energy:** oil and gas, wind, solar, and power

- **Agriculture and farming:** farms, ranches, and dairy

- **Parks:** national, state, city, and neighborhood

Key Use Cases

Asset optimization
5G enabled environmental-friendly solutions that use real-time edge compute analytics to optimize operational resources

Predictive maintenance
Proactively monitor, assess, and manage connected assets and equipment in real time by quickly detecting and responding to irregularities and faults

Remote operation
Remote automation and control of processes (e.g. agriculture operations, oil processing) supports cost-efficient production

Capacity forecasting
Asset owners balance and predict generation and delivery of energy in real time to align resources with demand levels

Grid balancing
Real-time monitoring and management of distributed energy resources to ensure quality services

Source: IoT Brings Firms With Remote Assets Closer To Their Customers Forrester report and A Decoder Ring For Edge Computing Forrester report

5G and edge smart home use cases address entertainment, security, and home office environments

Interdevice automation
Localized machine such as image recognition

Business engagement
Product makers, telcos, and builders create new services and value exchanges.

- Control climate and comfort
- Optimize lighting
- Track resource consumption using smart meters
- Improve home security
- Control access
- Monitor home safety

Automation

Engagement

- Guide meal planning and preparation
- Assist with fitness, wellness, and personal care
- Enhance recreation, hobbies, and toys
- Augment gardening
- Play music and audio throughout the house
- Boost TV and gaming using 4K video and AR/VR gaming
- Improve family caregiving

Better human engagement
Healthier, more free time, and closer to friends and family

Source: Smart Homes Advance Toward Subscription Living Forrester report and A Decoder Ring For Edge Computing Forrester report

Smart cities

5G and edge are inextricably linked in smart cities. Local governments are deploying 5G networks to connect buildings, lights, and infrastructure to enhance citizen services and enable safer public environments.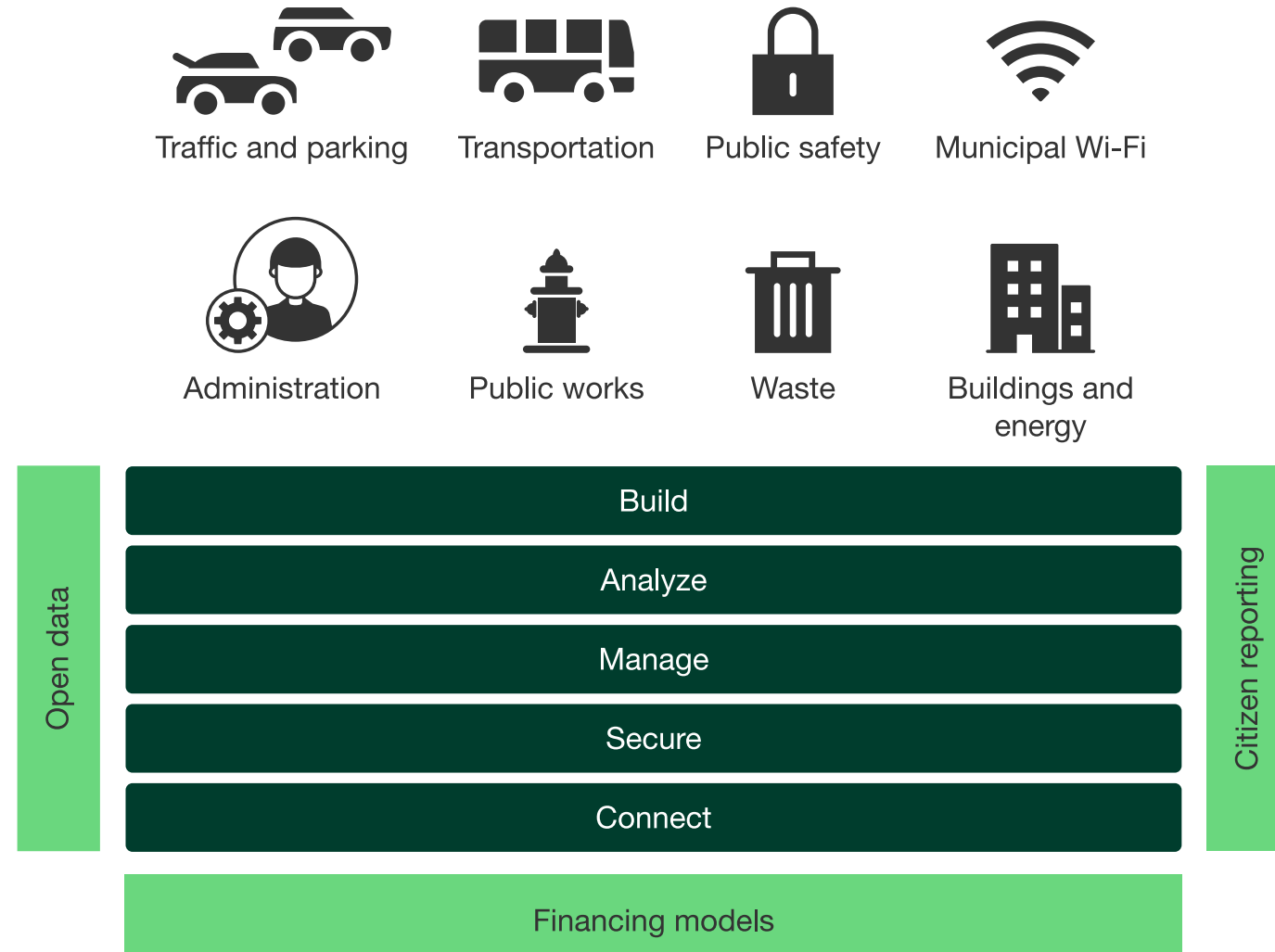 Edge computing in cities enables local governments to build and scale near-real-time services to citizens and contractors.

The COVID-19 pandemic will bolster momentum for new technology solutions to assist city stakeholders with public health monitoring and enforcement, particularly if government funding is provided to support these initiatives.

Traffic and parking   Transportation   Public safety   Municipal Wi-Fi

Administration   Public works   Waste   Buildings and energy

Open data

Build

Analyze

Manage

Secure

Connect

Financing models

Citizen reporting

Source: Smart City Platforms Enable The Insights-Driven City Forrester report and A Decoder Ring For Edge Computing Forrester report

Smart lighting is often the basis for deploying smart city infrastructure and applications

The light pole illustrates the Holy Grail of infrastructure reuse for new applications. A city first adopts smart lighting to reduce energy use and improve public safety. Even smarter cities leverage their lighting infrastructure to deliver new services. A smart city platform facilitates incremental app deployment and cross-app data access and integration.
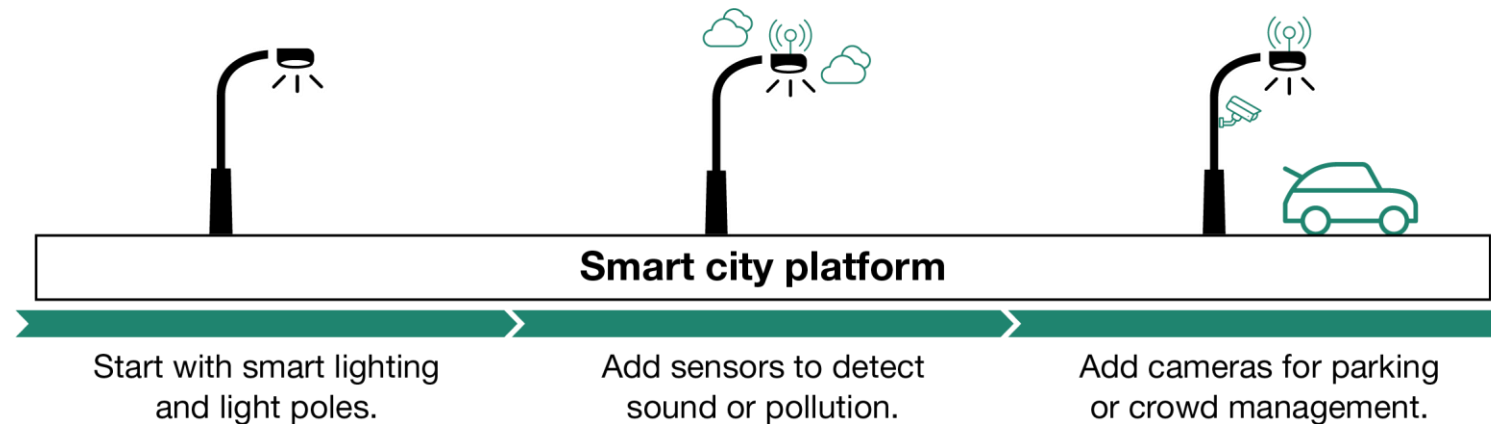
Smart city platform

| Start with smart lighting and light poles. | Add sensors to detect sound or pollution. | Add cameras for parking or crowd management. |

5G and edge value delivery in cities: crime prevention

Industries
Manufacturing, telcos, and retail

Human engagement (B2C, B2E, and P2P)
- ✓ Improve citizen safety and public property efficiencies

Interdevice automation (M2M/IoT)
- ✓ City lights, bus and train sensors, police cars, trash pickups, etc.
- ✓ Smart city hubs

Business engagement (B2B)
- ✓ Telcos, retailers, and city governments

Source: A Decoder Ring For Edge Computing Forrester report

Business problem

5G allows information gathered through sensors to be transmitted in real time to edge computing equipment and beyond. 5G-enabled security solutions incorporate edge technologies, cameras, and sensor-enabled equipment around public properties. Often, these solutions only record individual thefts and thus do little to help track and then catch moving criminals.

Latency	* 5G ultra-low latency transmits security incidents in real time. * Real-time insight from computer vision (cameras)
Cost	Data not stored in cloud
Security	Raw data doesn't leave city confines; 5G enables critical machine type communication required for security solutions.
Intelligence	Helps retailers reduce loss from stolen deliveries; ensures safety of citizens and visitors
Scale	Can replicate in neighborhoods with required 5G network infrastructure deployment
Resiliency	Doesn't depend on cable IP for some functions

5G and edge computing value

Ultra-high bandwidth/low latency 5G and edge enable real-time image recognition using external cameras. Captured video is passed to the smart city hub and evaluated to Identify theft situations, using integrated device security systems to call police and pass vehicle tracking information to them. Telcos use their 5G networks to connect urban cameras to edge applications running on their mobile base stations.

5G and edge technologies

- Computer vision does edge machine learning on smart cameras and home hubs.
- Smart city hub coordinates response with police, locks doors if unlocked, and possibly sounds a crime siren.
- 5G networks and telco mobile edge computing tracks vehicle with urban cameras.

5G and edge enable cross-market secure data sharing to help expand smart city insights and value delivery
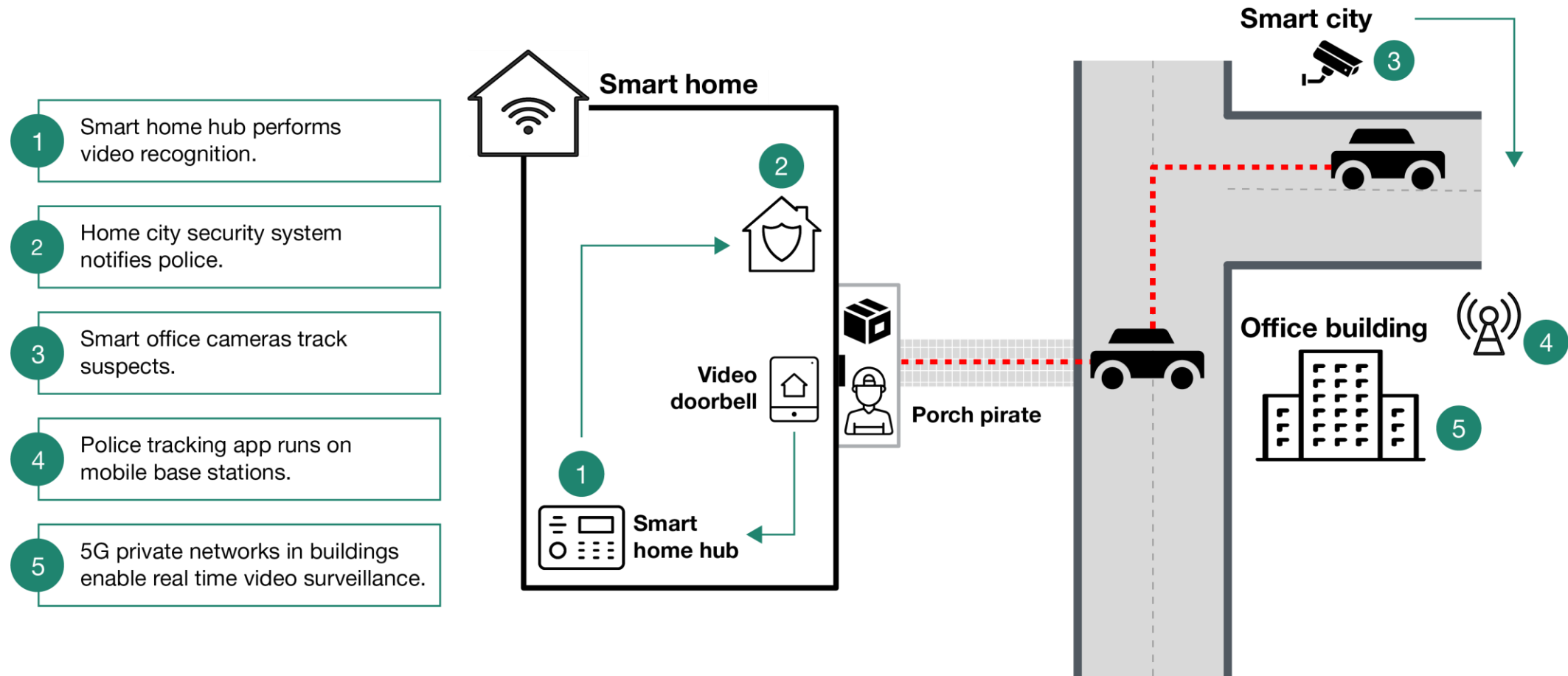
1. Smart home hub performs video recognition.

2. Home city security system notifies police.

3. Smart office cameras track suspects.

4. Police tracking app runs on mobile base stations.

5. 5G private networks in buildings enable real time video surveillance.

Smart home

Smart city

Video doorbell

Smart home hub

Porch pirate

Office building

Source: A Decoder Ring For Edge Computing Forrester report

Research insights agenda

Emerging 5G networks promise latency and bandwidth benefits

5G powers IoT, automation, and edge computing

Edge computing transforms captured data into intelligent insight

5G and edge market adoption and key use cases

Vendor landscape

Recommendations

Vendors provide device management, comms, security, and software foundation for 5G networks and edge management

Cloud vendors
- AWS
- Google Cloud Platform
- Azure

Locally deployable converged platforms with onboard cloud services for storage, compute, AI, and more; all also providing CDN services at their metro locations; some expanding reach into 5G via telco partnerships

Telcos
- AT&T
- Orange
- Telefónica
- Verizon
- Vodafone

Deploying 5G networks and establishing relationships with edge device manufacturers; offering edge management at the network edge endpoints; providing edge compute services themselves or endpoint capacity that can be rented
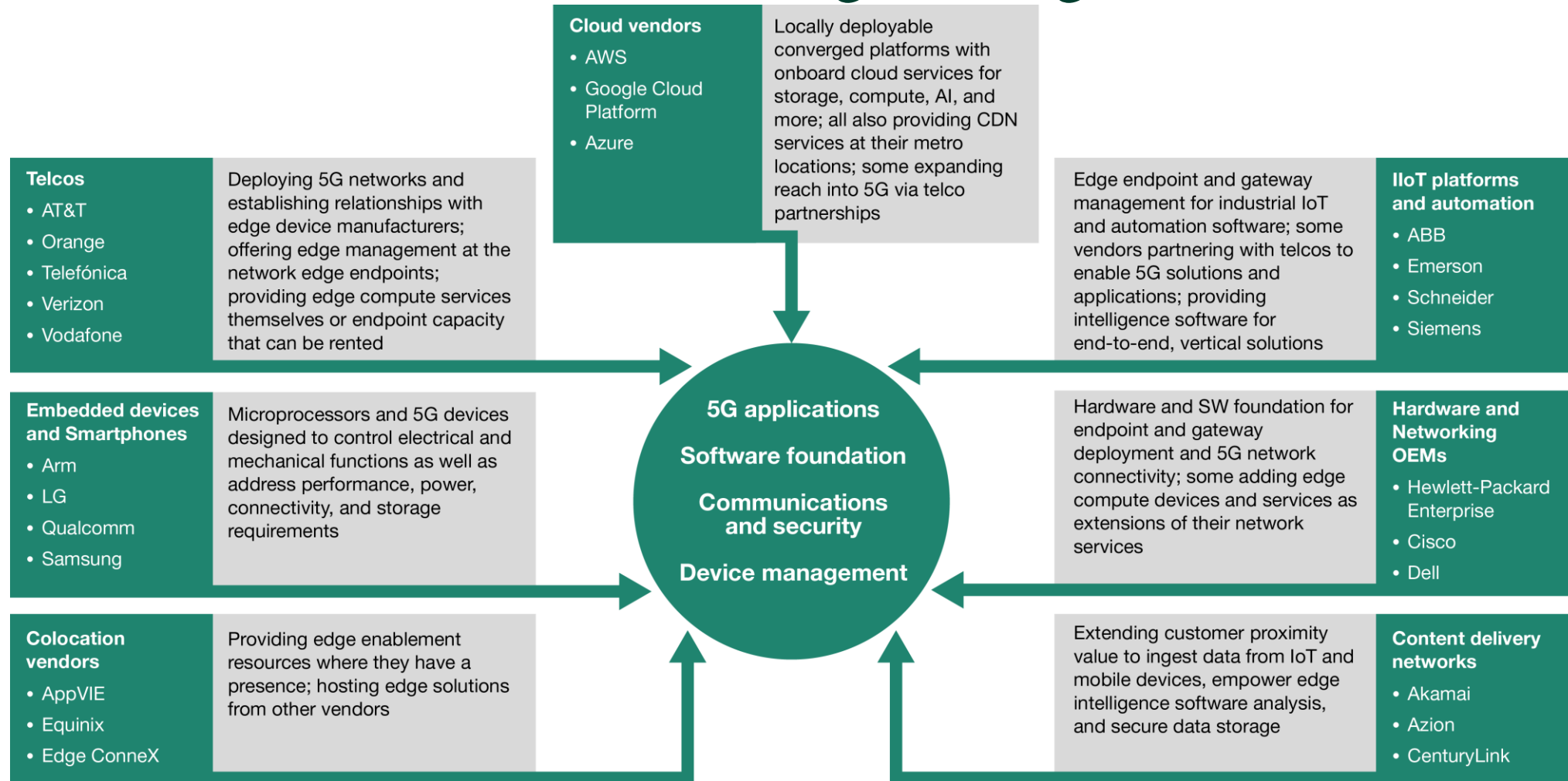
Edge endpoint and gateway management for industrial IoT and automation software; some vendors partnering with telcos to enable 5G solutions and applications; providing intelligence software for end-to-end, vertical solutions

IIoT platforms and automation
- ABB
- Emerson
- Schneider
- Siemens

Embedded devices and Smartphones
- Arm
- LG
- Qualcomm
- Samsung

Microprocessors and 5G devices designed to control electrical and mechanical functions as well as address performance, power, connectivity, and storage requirements

5G applications
Software foundation
Communications and security
Device management

Hardware and SW foundation for endpoint and gateway deployment and 5G network connectivity; some adding edge compute devices and services as extensions of their network services

Hardware and Networking OEMs
- Hewlett-Packard Enterprise
- Cisco
- Dell

Colocation vendors
- AppVIE
- Equinix
- Edge ConneX

Providing edge enablement resources where they have a presence; hosting edge solutions from other vendors

Extending customer proximity value to ingest data from IoT and mobile devices, empower edge intelligence software analysis, and secure data storage

Content delivery networks
- Akamai
- Azion
- CenturyLink

Note: Sample vendors are not an all-inclusive list.
Source: A Decoder Ring For Edge Computing Forrester report

Cloud vendors are extending their ability to address 5G hybrid edge cloud solutions

- Microsoft
  - Vodafone and AT&T's Network Edge Compute (NEC) integrates Microsoft Azure cloud services into its virtualized 5G core network edge in specific sites.
  - Azure Edge Zones (In preview) enable carriers to connect Azure services directly to 5G networks in the carrier's datacenter.

- Amazon Web Services (AWS)
  - AWS Wavelength compute and storage services are embedded at the edge of Verizon's 5G network, enabling connections to applications that require ultra-low latency at the edge of the network.
  - AWS Wavelength will be available first in the UK and Germany on the Vodafone 5G network, expanding to other Vodafone markets across Europe.

Key components of the leading cloud vendors' edge solutions

Cloud layer
Centralized enterprise data centers with scalable, reliable IT resources and processes for governing, storing, and processing data, requiring global awareness across a population of devices and scenarios.

Edge gateways
Gateways that provide compute, storage, and network connectivity for industrial assets and sensors that are connected physically or wirelessly. These gateways link connected devices to distant servers or to cloud services. These gateway devices host code, apps, and data onsite and enable faster local response.

Edge compute devices
A server or group of compute devices that extend cloud-type capabilities to a single industrial site (e.g., factory, ship, or oil field) and interface with groups of edge devices. Key functions include providing reliable network downstream and limited network upstream service. Edge compute can extend the capabilities of data historians.

Embedded components
Asset-level hardware with domain-specific sensors; purpose-built computing systems that measure and control assets and equipment. Embedded devices connected to the internet are called smart, and devices not connected to the internet are called dumb.

Research insights agenda

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Recommendations

Recommendations

- Study the distinctions between what type of insights you need in real time, near-real time, and acceptably longer. Based on this analysis, look to spread your compute analysis architectures between endpoints, edge gateways, and traditional data center or cloud capacity.

- Use edge compute to assess which collected data sets need to be/should be moved out to edge gateways or back to your corporate traditional infrastructure. While 5G provides greater capacity, you'll still likely run into capacity limits on high volumes of IoT and mobile data sets.

- Focus edge deployments and solutions on expanding customer values, especially in proximity to your most valued and largest customers. Don't lose sight of the overarching drive to win, serve, and retain customers.

- Prioritize end-point employee empowerment and creation of digital twins.

- Don't think of 5G only as a telecom WAN option. For example, enterprises can use private 5G networks in situations similar to a wireless LAN. In addition, 5G solutions will coexist with other wireless networking technologies. For example, 5G capacity is also being added to Wi-Fi networking solutions.

Recommendations (cont.)

- Align your 5G-enabled edge priorities with a 5G network, data analytics, and deployment strategy.
  - Each telco and equipment vendor brings different features to market along different timelines.

- Evaluate opportunities to deploy real-time edge applications that require 5G bandwidth and latency capabilities.
  - Video analytics: quality assurance, safety, surveillance, and compliance
  - Transportation applications: route optimization, traffic management, and telematics

- Use both 5G-enabled edge and cloud solutions, depending on the use case requirements.

- Assess requirements for managed edge services to:
  - Assess and monitor 5G device health.
  - Manage 5G network connectivity.
  - Provide remote support and diagnostics of 5G devices.
  - Conduct 5G device firmware updates.
  - Manage SLAs.

Companies interviewed for this report

We would like to thank the individuals from the following companies who generously gave their time during the research for this report.

- ADlink

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- Atos

- Cisco

- Cloudera

- Dell Technologies

- HCL

- HPE

- Locus Technologies

- Marlabs

- Mavenir

- ObjectBox

- Redis Labs

- SAP

- Schneider Electric

- ServerFarm

- Signify

- TCS

- Verizon

- Vertiv

- VMware

Thank You.

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