PitchBook

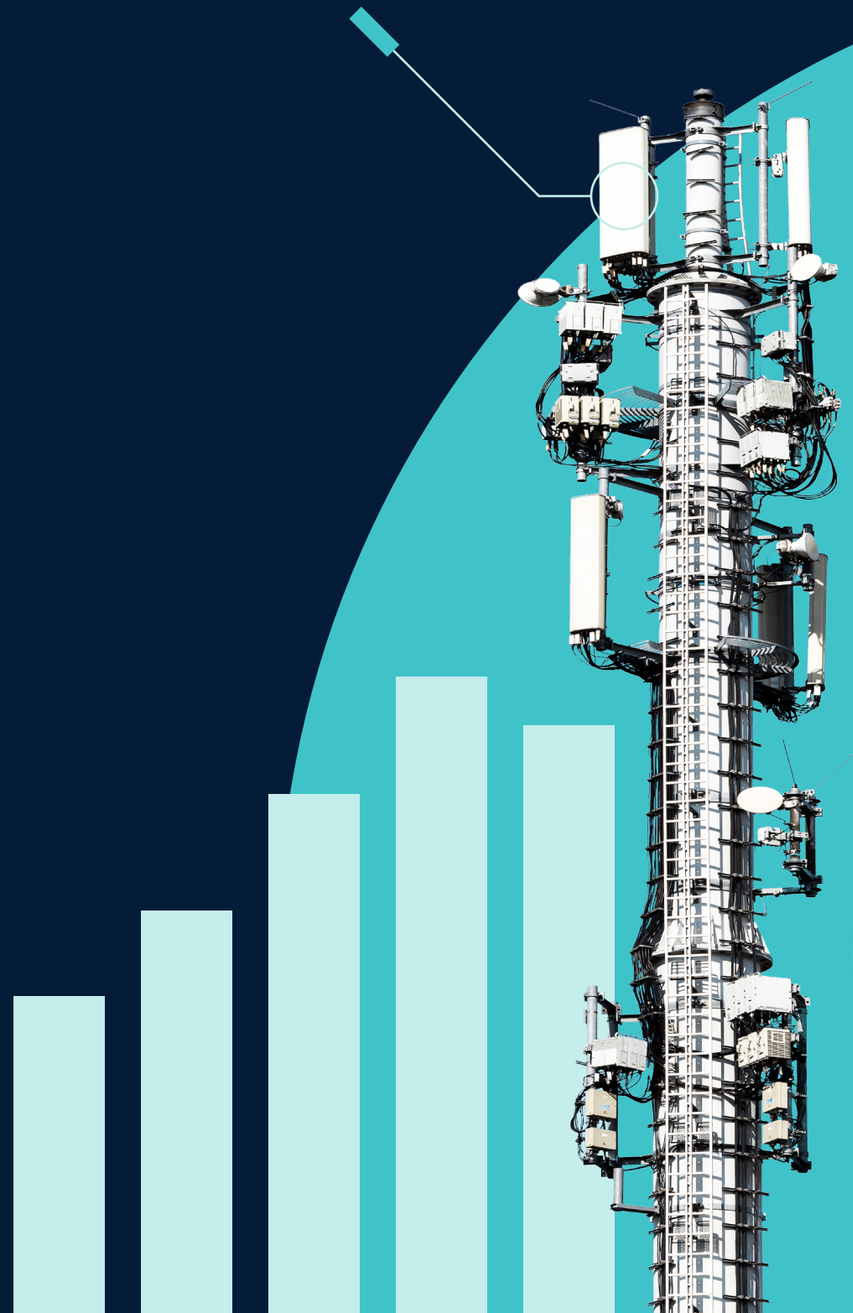
EMERGING TECH RESEARCH

Internet of Things (IoT) Overview

Industry and taxonomy update with latest VC activity

2023

Published September 28, 2023



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We are adding PitchBook Exit Predictor probabilities to our Emerging Technology Research reports. PitchBook's proprietary VC Exit Predictor estimates the probability that a startup, or VC-backed company, will successfully IPO, be acquired, or merge. The tool is available exclusively to PitchBook subscribers.

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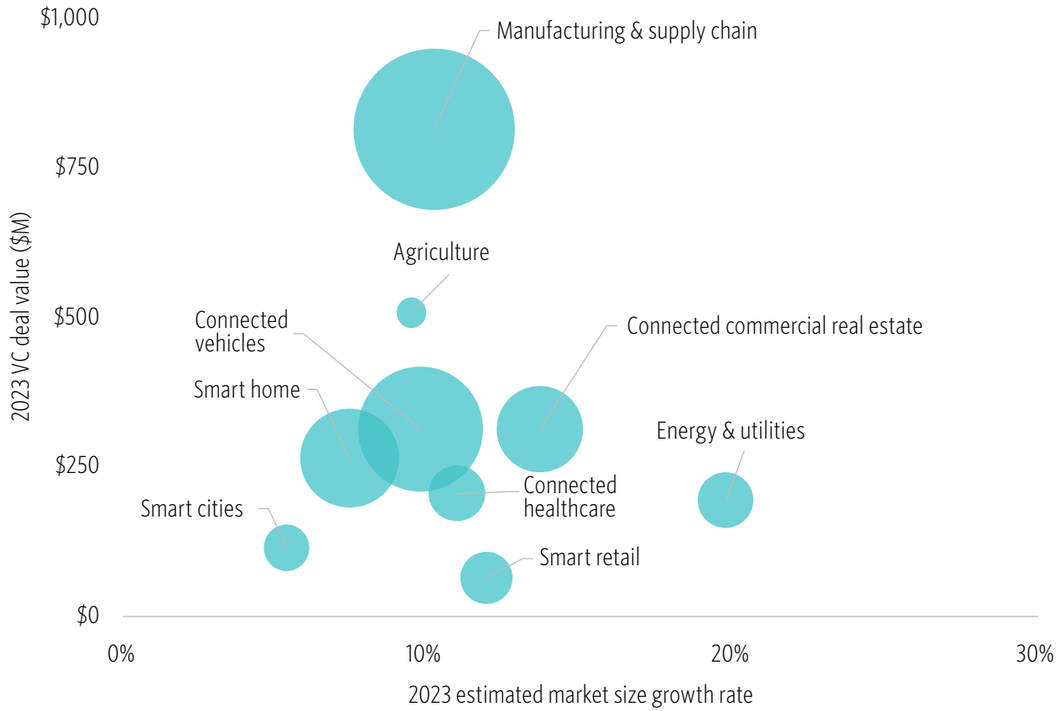
For previous updates, as well as our complete Internet of Things research, please see the designated analyst workspace on the PitchBook Platform.

Vertical overview

IoT can benefit from rapid deployment of AI analytics and move beyond machine data analysis to device-level intelligence and conversational systems. Adoption of advanced AI analytics remains relatively limited in industrial settings relative to the IT industry. A recent IDC survey found that no industry has more than 14.3% of enterprises investing $5 million or more in AI, led by automotive and followed by consumer goods and oil & gas exploration.[1] Even so, we see opportunities for generative AI to improve opportunities for field operators to engage with digital systems in new ways. Experienced operational staff resist using advanced analytics, and younger talent often avoids industrial fields due to a perception of low innovation, limiting the adoption of industrial analytics. With the rise of generative AI, a range of operational users can employ natural language to ask analytical questions in their own language and receive relevant results, making AI appealing to both new and experienced workers. Additional foundational models will be required to adapt to industrial contexts and can present new opportunities for startups.

We estimate the market opportunity for IoT startups (excluding services startups) in our use-case taxonomy will reach $535.1 billion by year-end 2023, growing 9.9% over 2022. As we anticipated, in 2023, growth has declined, leading us to revise our estimate from H2 2022 downward. Smart cities and manufacturing & supply chain stand out for revenue growth. Use cases growing more than 20% in revenue in 2023 include manufacturing operations, connected heavy trucks, and residential electricity metering. Manufacturing & supply chain has begun to stand out in VC funding after lagging in the past given high incentives for reshoring manufacturing in the US. High growth in smart electricity meter deployment is restoring growth in energy & utilities, which is not yet attracting high VC funding to match. Low growth in connected vehicles, smart home, and smart cities is limiting VC investment.

2023 IoT subsegment market size ($B) by VC deal value and estimated market size growth rate*



Source: PitchBook Emerging Tech Research • Geography: Global • *As of December 31, 2022

Note: Data is based on analyst segmentation of companies with more than $5 million VC raised.

1: "IDC Survey Spotlight: Artificial Intelligence Investment for Industrial IoT Operations," IDC, September 2023.

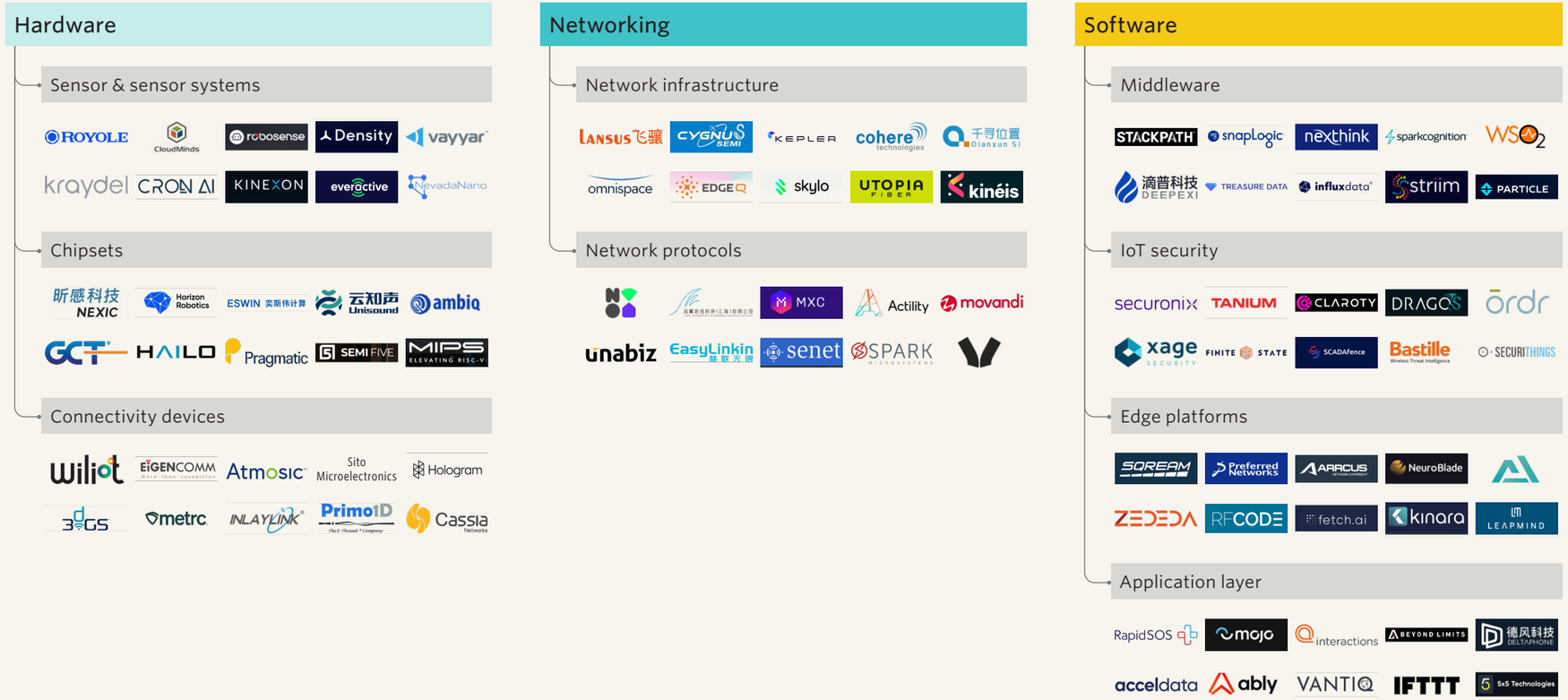
IoT landscape

1. Hardware
2. Networking
3. Software
4. Connected buildings
5. Connected services
6. Industrial

IoT VC ecosystem market map

Click to view the interactive market map on the PitchBook Platform.

Market map is a representative overview of venture-backed or growth-stage providers in each segment. Companies listed have received venture capital or other notable private investments.



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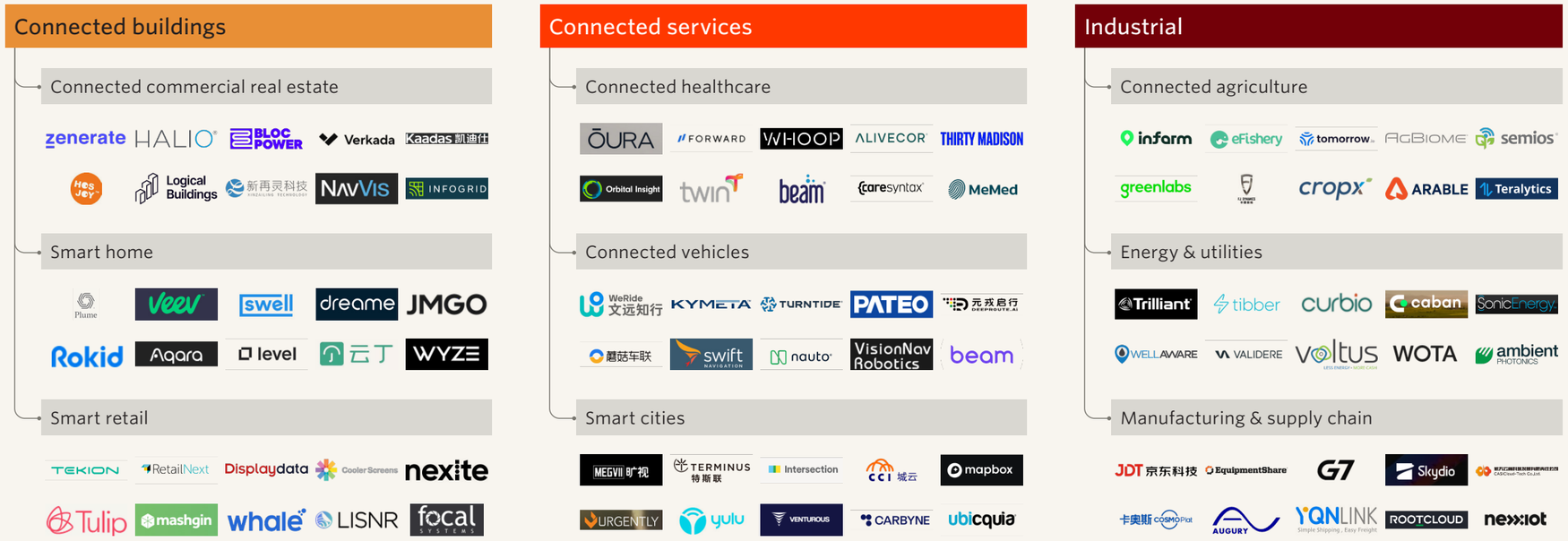
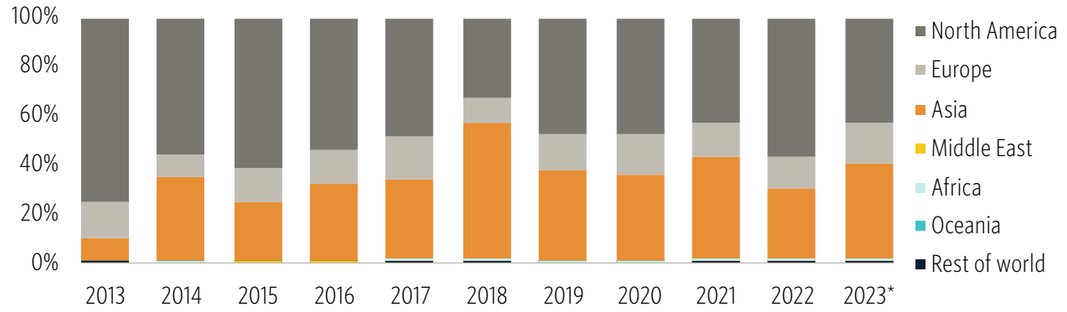


VC activity

IoT VC funding dissipated in North America since Q3 2022, with only $2.3 billion invested in the vertical in H1 2023 after reaching $12.5 billion in 2022. Asian VC funding is on pace to surpass North American funding for the first time since 2018, suggesting a regional shift in leadership in the vertical. Europe has led implementation of some types of IoT yet also lags Asia in VC funding. IoT hardware has remained relatively resilient, with both semiconductors and sensors on pace to raise over $1 billion in 2023. No other categories are on pace to do so, after six categories reached $1.0 billion each in 2022. While some leading companies are well capitalized with little need to raise, we see limited exposure of the IoT vertical to the leading theme of generative AI and thus little investor appetite in the current capital-constrained environment. We tracked only five VC megadeals in H1 2023 in North America and Europe compared with six in Asia. We also tracked 34 flat or down rounds, demonstrating the limits to valuation growth.

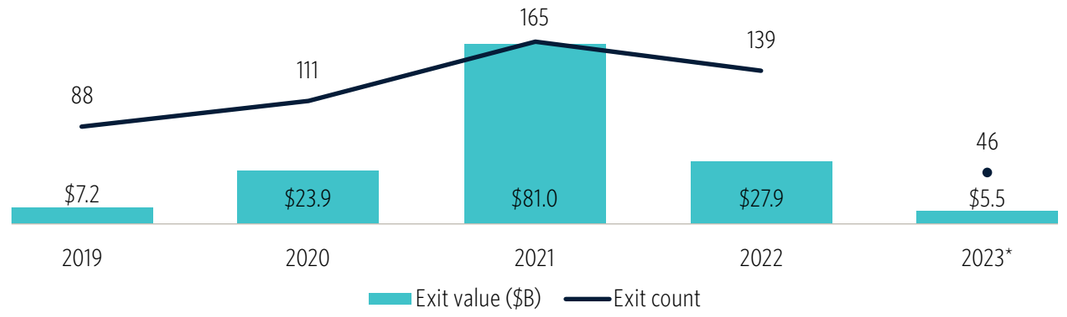
Disclosed exit value has nearly entirely derived from the Chinese IPO market, which remains open for early-stage companies. Seven China-based IPOs have closed during 2023 after 10 in 2022. IoT remains a cornerstone of China's governmental technology strategy as reinforced in the most recent five-year plan passed in 2021.[2] Arm's public listing demonstrates how large companies focused on IoT and consumer electronics can grow if they establish central market positions in hardware design. The company is pricing over $50 billion in its public listing based on expectations for future growth in edge AI applications. The success of this listing may affect growth expectations for startups integrating Arm's designs and collecting data from intelligent devices including Arm's. Arm has also been one of the most active acquirers in IoT, which means its listing could further grow companies in its ecosystem.

Share of IoT VC deal value by region



Source: PitchBook • Geography: Global • *As of June 30, 2023

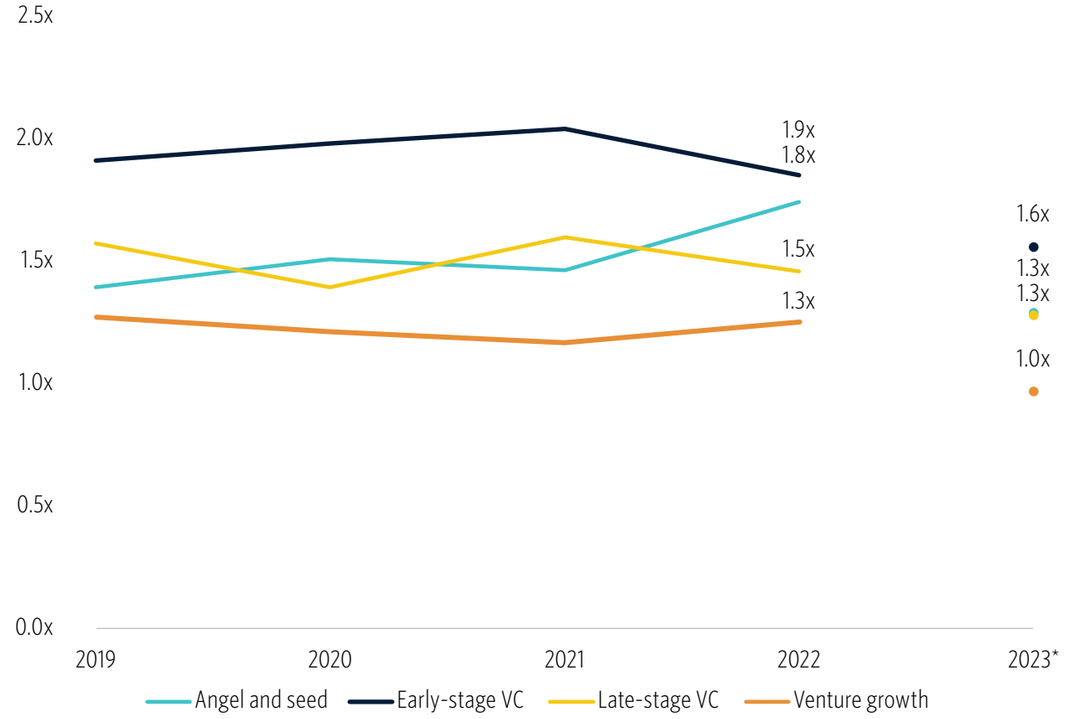
IoT VC exit activity



Source: PitchBook • Geography: Global • *As of June 30, 2023

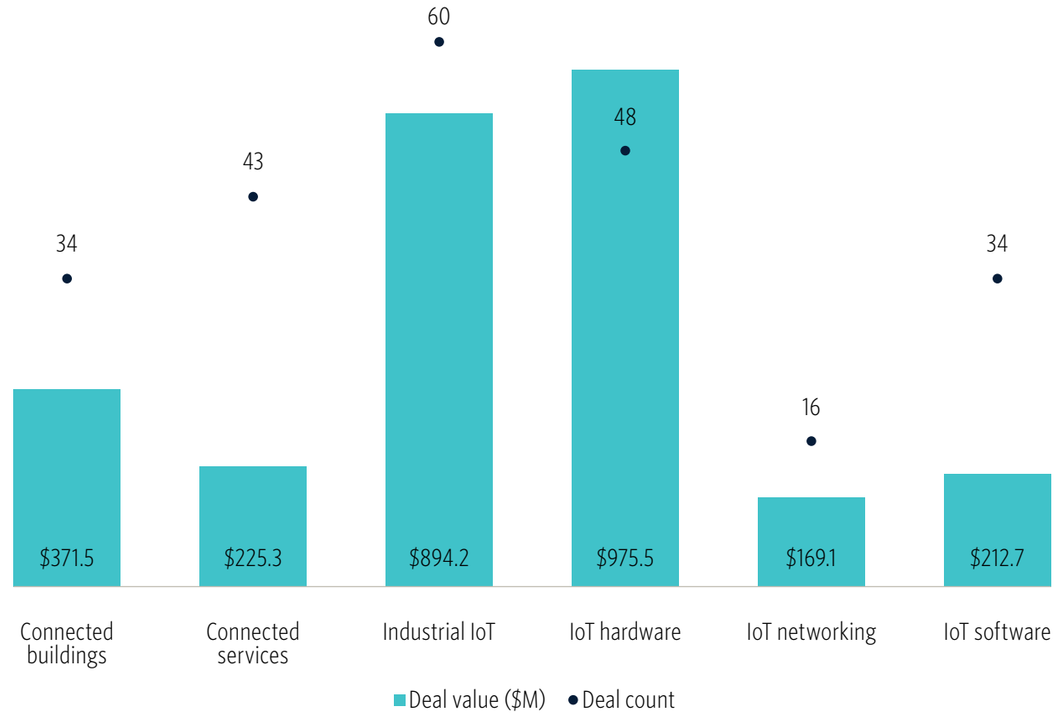
2: "Outline of the 14th Five-Year Plan (2021-2025) for National Economic and Social Development and Vision 2035 of the People's Republic of China," The People's Government of Fujian Province, August 2021.

Median IoT VC pre-money valuation step-up by stage



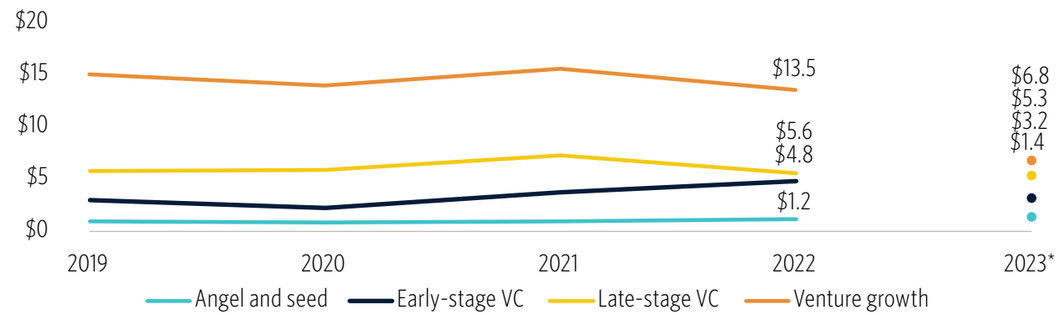
Source: PitchBook • Geography: Global • *As of June 30, 2023

Q2 2023 IoT VC deal activity by segment*



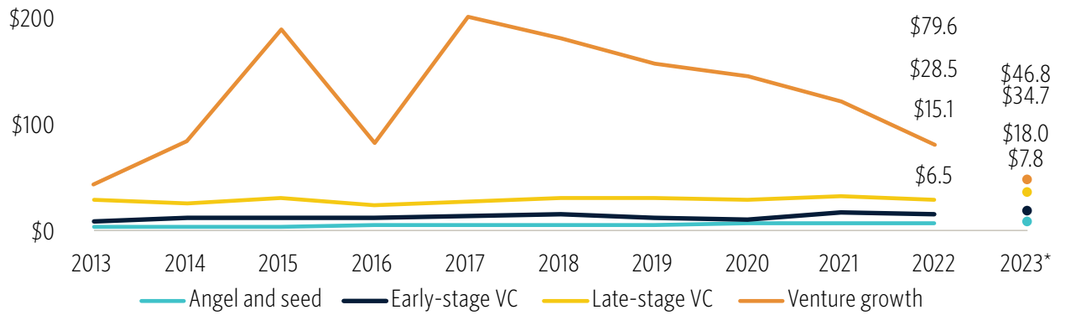
Source: PitchBook • Geography: Global • *As of June 30, 2023

Median IoT VC deal value ($M) by stage



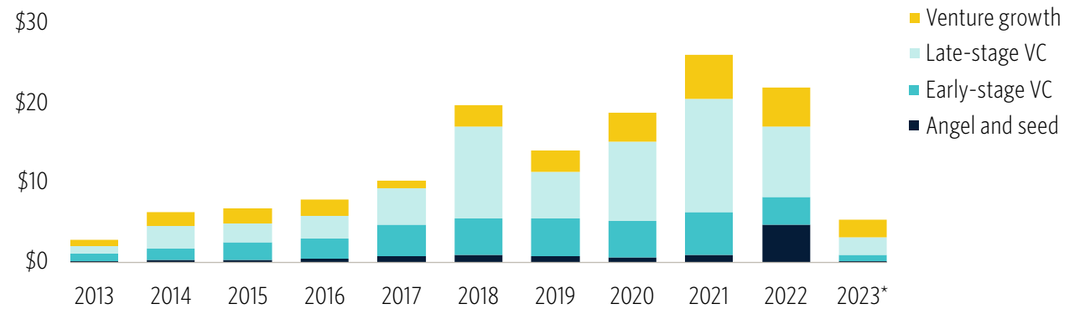
Source: PitchBook • Geography: Global • *As of June 30, 2023

Median IoT pre-money valuation ($M) by stage



Source: PitchBook • Geography: Global • *As of June 30, 2023

IoT VC deal value ($B) by stage



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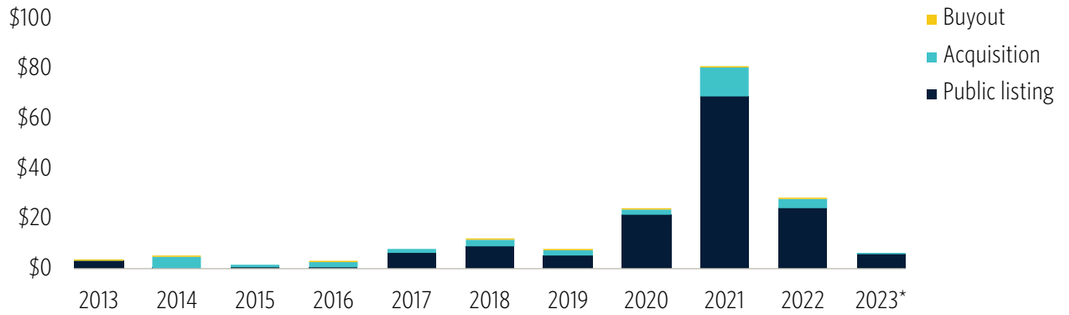
IoT VC exit value ($B) by type



Source: PitchBook • Geography: Global • *As of June 30, 2023

Key IoT VC exits by exit value in H1 2023*

Company	Close date (2023)	Segment	Subsegment, category	Exit value ($M)	Exit type	Acquirer(s)
Anyka Microelectronics	June 27	IoT hardware	Chipsets, system on chip	$439.9	Public listing	Haitong Innovation Capital Management
Hicon	June 20	IoT software	Application layer, application enablement	$1,595.9	Public listing	N/A
Praemo	June 14	Industrial IoT	Manufacturing & supply chain, machine visibility & monitoring for predictive maintenance	N/A	Acquisition	Stream Systems
Panthronics	June 1	IoT hardware	Chipsets, system on chip	N/A	Acquisition	Renesas Electronics
Phone580	May 17	IoT software	Application layer, application enablement	$437.8	Public listing	N/A
Proxy	May 9	Connected buildings	Connected commercial real estate, smart building	N/A	Acquisition	Oura
Intellifusion	April 4	IoT hardware	Chipsets, system on chip	$1,696.7	Public listing	N/A
MonstarLab Holdings	March 28	IoT software	Application layer, application enablement	$170.3	Public listing	Tokyo Stock Exchange
Movella	February 10	IoT hardware	Sensors & sensor systems, sensors	$537.0	Public listing	Pathfinder Acquisition
Fatmap	January 24	Connected services	Connected mobility, connected car	N/A	Acquisition	Strava

Source: PitchBook • Geography: Global • *As of June 30, 2023

Segment overview

Hardware

Leading opportunities include edge AI semiconductors, microsensors, SIM cards, and wireless power.

Networking

Leading opportunities include low earth orbit satellites, private 5G, and connectivity management.

Software

Leading opportunities include data integration, IoT/OT security, and edge AI compression.

Industrial IoT

Leading opportunities include predictive maintenance and smart manufacturing.

Connected buildings

Leading opportunities include building twins, smart locks, and smart home protocols.

Connected services

Leading opportunities include automotive software, senior care monitoring, and public safety.

IoT hardware

Overview

IoT hardware refers to the underlying technology powering devices that collect and route data to IoT networks. Each IoT device must have three characteristics: sensing or actuation capabilities to either acquire data or turn the device on to send a signal; computation ability to, at minimum, enable data control; and communication with the internet. Innovations are occurring in each of these areas, presenting fundamental improvements to the efficiency and capacity of IoT devices in all applications. We divide these innovations into the following subsegments:

Chipsets

Microcontrollers: Small computers on single integrated circuits. These computers contain at least a processor core, memory, and programmable input/output controls, referred to as peripherals. These peripherals include timers, interfaces to external systems, and storage.

System on a chip (SoC): SoCs are usually built around a microcontroller but have more complex architecture and more integrated peripherals, including voltage regulation and power settings. These systems include all the necessary peripherals and memory for certain IoT applications, while microcontrollers must be configured in custom systems. They are optimized for low power consumption, wireless connectivity, and real-time data processing.

Sensors & sensor systems

Sensors: Devices that measure specific parameters in real-world conditions including environmental conditions, motion, images, and chemical levels.

Sensor systems: Assemblages of sensors and chipsets that empower specific IoT use cases.

Connectivity devices

Radio frequency identification (RFID): Tags that absorb electromagnetic energy to transmit simple, unique codes. RFID tags are common components of near-field communications.

Network-specific antennas and routers: IoT networks often require specific endpoint-level routers or antennas. Examples of these include Bluetooth routers and RFID antennas that must be deployed at the local level to detect low-range signals from end devices and transmit them to central gateways. This category can also include subscriber identity module (SIM) cards.

Gateways: Transmitters that filter and format data from IoT devices in connection with IoT networks.

Innovations in these areas require substantial capital investment. Incumbents have an innovator's dilemma as fundamental improvements in hardware performance can disrupt the market for their legacy products. As such, startups may have a competitive advantage as they can more freely experiment with new architectures.

Industry drivers

Cost of sensors, bandwidth, processing, and storage declining precipitously: Microcontroller pricing remains high after pandemic-induced shortages, but those shortages are easing, and price declines should occur in 2024. The open-source RISC-V protocol can also lower the price of semiconductors.

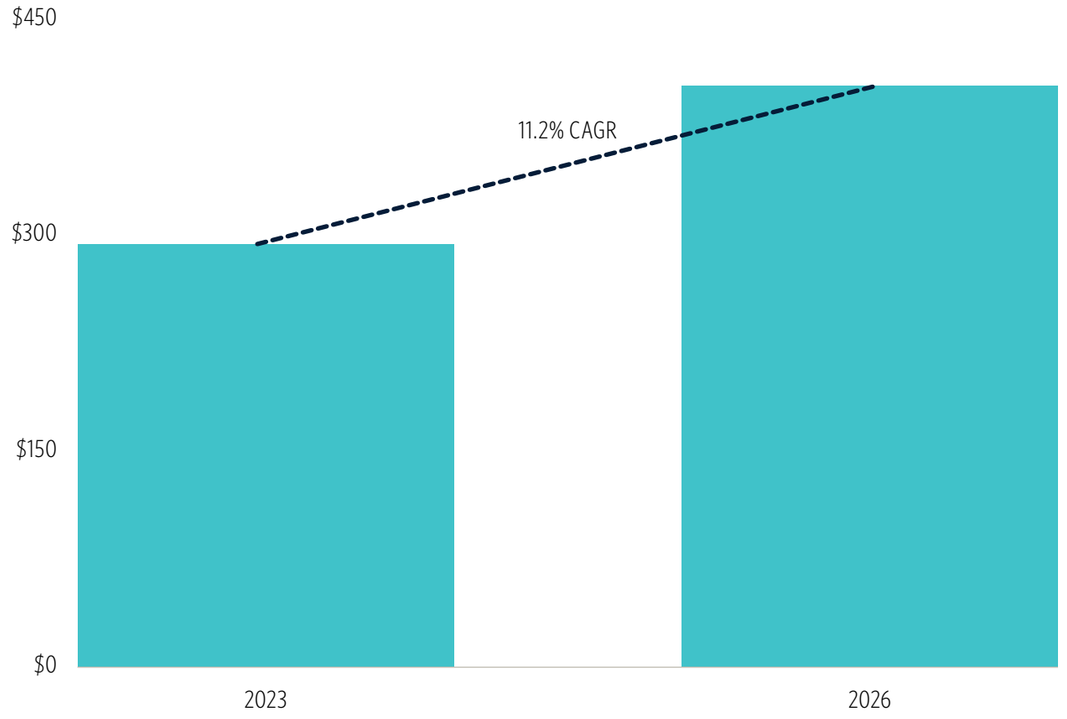
Improving connectivity: The increasing prevalence of wifi and high-speed cellular connections makes connected devices easier to deploy.

Emerging business models for device data: Device vendors are increasingly financing sensors based on performance data and cost savings, which improves adoption rates and encourages innovation in device performance.

Market size

We estimate the IoT hardware market to be roughly 33% of the IoT industry, as measured by end-user spending, making it the largest market for enabling technology. This estimate is limited to the use cases listed in this report: industrial IoT, connected buildings, and connected services. We believe the market will reach $235.1 billion in 2023, growing at a 12.6% CAGR to $332.9 billion in 2026. Because our bottom-up estimation methodology is based on actual device sales data in specific use cases, this estimate falls below other industry estimates, which peg the industry closer to $1 trillion in revenue based on top-down assumptions of device counts. Our forecast has declined since H2 2022 due to disappointment from manufacturing & supply chain device sales.

IoT hardware market size estimate ($B)*



Source: PitchBook Emerging Tech Research • Geography: Global • *As of June 30, 2023

Business model

Microprocessor companies traditionally use a unit sales model based on supply and demand of individual units. This business model requires inventory forecasting and cash flow management and forces customers to accept technology risks by committing to deploying devices in unique operating environments.

Device manufacturers are increasingly developing hardware-as-a-service (HaaS) business models, targeting specific use cases. Device installations are financed and then customers pay back out of savings or through a lease agreement. Vendors can also sell data packages and supply sensors necessary to support contracted data volumes. These models offer manufacturers improved inventory forecasting, faster sales cycles, and potentially higher margins.

Opportunities

Edge AI semiconductors

NVIDIA's recent financial results and the Arm IPO demonstrate the scale of companies that can be built in advanced semiconductors. While NVIDIA has benefited from gaming and data centers more so than the embedded edge, Arm has earned nearly $3 billion in revenue in each of the past two years due to market leadership in consumer electronics and IoT chip design. In the company's F-1, the total addressable market of embedded IoT chips was estimated at $41.5 billion as of 2022.[3]

Arm has made research breakthroughs in voice recognition and image detection. As AI becomes more powerful and ubiquitous, IoT devices will need to interface with the latest models to take advantage of new computing paradigms in augmented reality and localized knowledge models in automobiles, workstations, and mobile phones.

Automotive and edge computing demands are driving more commercial agreements for inference-focused chips than for cloud training chips. In Q2 2022, edge AI chip startup Hailo announced a partnership with leading automotive chipmaker Renesas for self-driving applications. Renesas is on pace to generate $5.0 billion in automotive revenue in 2023 and was only the third-largest automotive chipmaker in the world in 2021, demonstrating the scale of this market.[4, 5] The company plans to package Hailo neural network processors with its advanced driver assistance system chips to facilitate autonomous driving features. In Q3 2022, edge AI chip startup SiMa.ai raised a $67.8 million Series B1 extension in part to pursue the automotive market in a strategic pivot. The company attributed the decision to the size of the automotive opportunity in computer vision. During the fundraising round, the company hired veteran automotive executive Harald Kroeger as president of automotive, demonstrating the urgency of the opportunity and belief of investors in the pivot.

MEMS for IoT

Microelectricomechanical systems (MEMS) sensors are susceptible to disruption as new use cases emerge for the technology. Over the past 30 years, MEMS sensors have become a key

3: "Form F-1 Registration Statement," Arm Holdings Limited, August 21, 2023

4: "2Q 2023 Presentation," Renesas Electronics Corporation, July 27, 2023.
5: "Worldwide Automotive Semiconductor Market Shares, 2021: Established Vendors Continue Dominance," IDC, Nina Turner, July 27, 2022.

component of mobile devices. As the cellphone and tablet market created needs for new kinds of MEMS sensors, incumbents were displaced. The industry leaders in 2006—Texas Instruments, HP, and Canon—ceded market-leading positions to Bosch and STMicroelectronics by 2013. We believe a new wave of MEMS sensors are likely to be developed with key characteristics including low power consumption, event-driven sensing—which refers to asynchronous capture of environmental changes in real time, as opposed to a fixed rate of data capture—and piezoelectric transducers that transform environmental changes into electrical charges, as well as base materials that are cheaper than silicon, including paper or plastic. While the growth of these novel sensors will depend on the adoption of manufacturing and healthcare sensors, history shows that MEMS market leaders can scale to over $1 billion in revenue.

An innovative MEMS design company focused on a specific vertical could supplant incumbents in this space and capture market share. Qualcomm demonstrated chipmakers' M&A appetite for the technology with its $160.0 million acquisition of Vesper in Q3 2022. In Q1 2023, Movella went public via SPAC merger, earning a $537.0 million valuation, though the stock has declined significantly since listing. The company's revenue base remains under $50 million in the motion capture space. Also in Q1 2023, NevadaNano raised a $30.0 million Series C led by leading strategic investors Honeywell Ventures and Emerson Ventures to detect gas leak emissions, citing the company's patent portfolio of 30 patents.

eSIM and iSIM: Roaming IoT devices require advanced connectivity chips to shift between cellular and noncellular networks without connectivity loss. Various approaches include embedded SIM (eSIM), which allows for programmable connectivity management instead of hard-coded carrier links as with SIM cards. Integrated SIM (iSIM) offers similar connectivity management yet is designed into silicon, with resulting form factor and power benefits. eSIM has not gained traction yet due to a lack of standards and low support from carriers. In particular, cellular networks such as NB-IoT do not work with most eSIMs on the market. Based on typical device bills of materials, SIM can contribute around 2% of total device revenue as a total addressable market (TAM), based on the current proportion of wireless connectivity costs to the overall system-on-chip costs. That suggests there will be a $7 billion TAM for the technology in 2023, based on the forecast size of the IoT hardware market.

Wireless power

Wireless charging holds the potential to revolutionize mobile devices by creating a new protocol in addition to wifi and Bluetooth. Radio frequency can deliver electricity reaching bandwidths of wired connections, thereby removing the need for battery power or energy harvesting. Radio frequencies can be transformed with techniques including multiple input/multiple output and beamforming, which can create high-throughput signals targeted in specific directions. Innovations in orthogonal frequency division multiplexing can enable power to be delivered in fractal patterns, thus avoiding objects and being blocked by people in a similar way as radio waves.

Given regulatory approvals, the distance charging market is poised to take off by 2024 and overcome the limitations of energy harvesting technology. Distance charging has not generated high revenues to date due to regulatory concerns and low efficiency. These concerns are being alleviated by improved performance in the field and support from mobile phone makers. In Q3 2023, Ossia made its 5.8-gigahertz transmitter kits available for sale for the first time, which may lead to a commercial ramp in 2024. At the early stage, Reach raised a $30.0 million Series B in an insider round led by deep tech VC firm DCVC.

Risks and considerations

Hardware is dominated by market leaders: Existing hardware is integrated into customers' processes with a high degree of technical lock-in. Control sensors and systems are typically interoperable only with legacy control software, making new device hardware incompatible with legacy systems. The sensitivity of industrial processes makes clients risk averse to piloting new products, and we believe leading suppliers, such as ABB, benefit from defensive moats and high switching costs. While emerging device manufacturers can overcome this lock-in effect by offering customers a holistic alternative to existing control systems, it is unlikely that product-market fit will exist for all new devices.

Device security is an unsolved problem: IoT devices today are commonly deployed with little security protection at the firmware level. This vulnerability enables hackers to take control of the devices and communicate with the enterprise network through them. This problem could worsen as more low-power IoT devices are deployed without the power budgets necessary to regularly interface with asset management systems. To solve this problem, IoT devices should be able to generate cryptographic keys at the device level. The prevalence of this practice is uneven, however, with notable exceptions including secure firmware from Bedrock Automation, OneSpin, Phoenix Technologies, and Secure-IC.

Low margins on devices: To compete against incumbents with strong pricing power, startups must offer competitive prices. Memory chips are currently constrained by low supply, driving up prices. This constrains already tight hardware margins and makes pricing power low. Companies should undertake best practices including fabless production—where manufacturing is outsourced—and competitive supplier networks to ensure low pricing. Full solution sales, including recurring software and service revenues, are a potential route around the cutthroat business models of hardware.

Networking

Overview

IoT networking refers to connectivity architectures that route device data to cloud networks. This segment includes both the network protocols that provide the underlying design for IoT connectivity, as well as the network-level hardware that transmits data from the edge to processing hubs and end users. We divide this segment into the following subsections:

Network infrastructure: This includes hardware that routes IoT data from the edge to the cloud. This hardware conducts specific frequencies across particular segments of the spectrum. Technologies within this subsegment include 5G technology, millimeter wave (mmWave) technology, low Earth orbit satellites, wifi transmission, and wireless modulation technology.

Next-generation networks: Next-generation networks refer to emerging network protocols based on both pre-existing and proprietary network devices. These networks tend to rely on unused frequency bands in the radio spectrum and leverage innovative signal modulation and device configuration architectures. Signal modulation can allow for multiple signals on the same frequency, thus allowing both strong and weak signals to connect to gateways. Technologies within this subsegment include decentralized physical infrastructure networks (DePIN), low-power wide-area networks (LPWANs), backscatter networks, metropolitan area networks, mesh networks, and private 5G.

Industry drivers

5G innovation: The pending finalization of cellular standards organization 3GPP's Release 19 will pave the way for enhancements in AI processing, connected vehicle use cases. Release 18 is already on track to bring advanced 5G to market in Q1 2024. While 5G rollouts have been limited to private networks and dense cities, these new standards will likely encourage innovation in more distributed use cases.

Commercial deployment of remote sensors in asset tracking, smart grid, and predictive maintenance applications: New applications of devices in wireless environments require the deployment of novel network architectures. Spending on distributed sensors for asset tracking and predictive maintenance is at the beginning of its growth curve as companies realize the economic benefits. To facilitate this growth, new private networks must be built, as well as new low-power connections to public networks.

Connectivity a major problem in IoT design: Behind security, connectivity is the second-biggest concern in IoT, according to a survey of device manufacturer Newark's customer base.[6] Additionally, communication reliability is the second-most-important aspect to consider when developing IoT solutions. We believe this problem stems from the plethora of wireless network options and difficulty of aligning device power and bandwidth requirements with cost-effective connectivity solutions.

6: "2021 Global IoT Trends Report," Newark, July 2021.

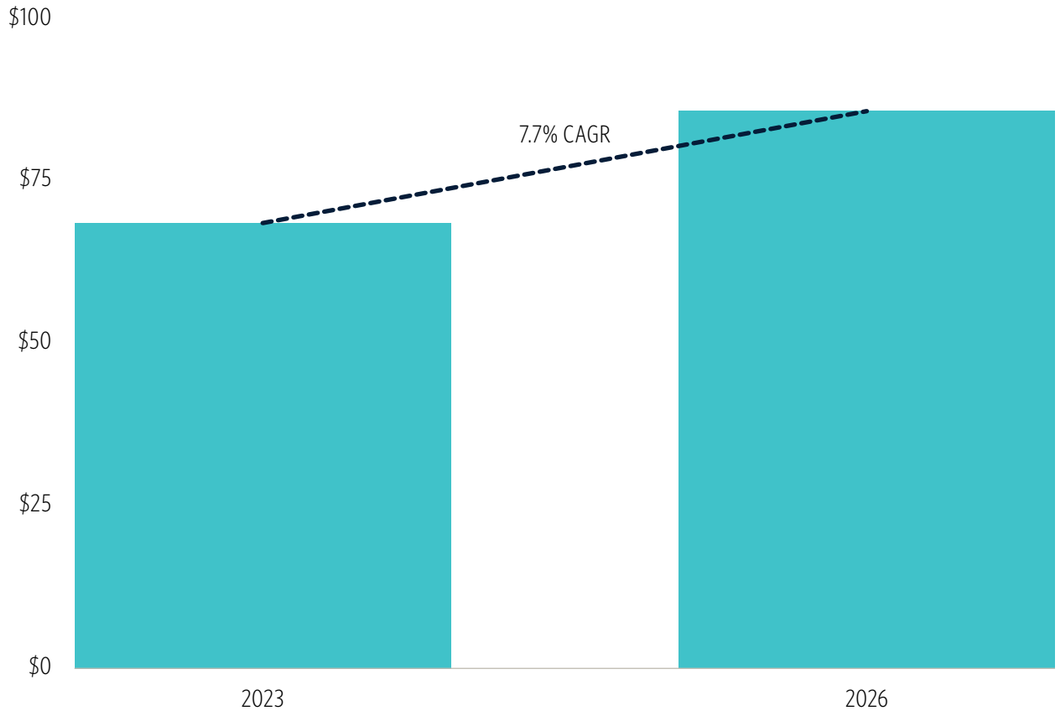
Market size

We estimate the IoT networking market will reach $54.3 billion in 2023 and will grow slightly slower than the IoT market at a 9.1% CAGR to an $84.1 billion market in 2026. While 4G, wifi, and Bluetooth have comprised the majority of gateway shipments and connectivity spending in 2023 so far, 5G and cellular LPWAN will grow the most quickly out to 2026 and capture half of device shipments. We believe that 5G connectivity spending will grow 67.0% annually to $3.9 billion in 2026, while LPWAN will grow 23.8%. The size of this market is dependent on the increasing deployment of wireless devices and formalization of connectivity protocols and could grow more slowly if IoT adoption does not increase overall and if 5G deployment stalls.

Business model

IoT networking companies can derive revenue streams from connectivity services, data management, and software subscriptions. Connectivity services include SIM services for secure and reliable data transmission between IoT devices and cloud platforms. Data management involves collecting, storing, analyzing, and processing data generated by IoT devices to derive insights. Subscription-based revenue models, based on factors like the number of devices and data usage, are a primary income source, enabling customers to access the IoT network and related services.

IoT networking market size estimate ($B)*



Source: PitchBook Emerging Tech Research • Geography: Global • *As of June 30, 2023

Opportunities

Low Earth orbit satellites: Innovative satellite coverage technologies can streamline network architectures by directly transmitting IoT data to central hubs. Currently, network architectures rely on complex connections of gateways and base stations that share bandwidth with many other devices. Satellites can transmit data to remote locations more cost-effectively than terrestrial networks. In comparison to an LTE network, satellites eliminate the need for transceiver stations, microwave systems, and repeaters, thereby creating a lower total cost of ownership in rural areas, where machine-to-machine IoT applications can be deployed.

Particularly, nano- and small-class satellites can be cost-effectively deployed in clusters. Swarm Technologies, Fleet, and Myriota have pioneered low-cost small-satellite technologies that can unlock remote IoT locations. SpaceX's first and only acquisition remains IoT satellite startup Swarm for an estimated $524.0 million in Q4 2021. The acquisition has played a role in SpaceX's cellular connectivity strategy, including for IoT devices. In Q3 2023, Open Cosmos raised a $50.0 million Series B from impact-oriented investors to improve satellite connectivity for energy and climate monitoring, demonstrating that specific use cases can still be addressed by startups. Amazon's pending Project Kuiper will receive $10 billion in investment for a global constellation of an estimated 3,236 low Earth orbit satellites. This will challenge startups to launch competing networks yet offers opportunity for hardware and software services companies.

Private 5G networks: While 5G could take until 2028 to achieve ubiquity in IoT as outlined in our Q4 2019 report, prototypes of the network are being deployed at individual facilities to enable high bandwidth with latency that is 50 times lower than 4G LTE and can support as many as 100 times more devices per square foot. 33 new private cellular networks were disclosed in H1 2023, according to IDC research.[7] More than half of new private cellular networks are based on 5G, suggesting the technology is preferred for industrial customers. These networks will include mmWave hardware, which provides connectivity at high frequencies. In Q1 2023, HPE acquired 5G connectivity vendor Athonet for an estimated $490.0 million to align with its Aruba networking product suite. The company offers hardware-agnostic connectivity management software and completed over 450 installations. With the acquisition, HPE is taking an explicit bet that 5G's benefits will be realized by enterprises rather than consumers. Other networking leaders may make similar inroads to the space as private networks scale.

Connectivity management: Specialist service providers are disrupting conventional carriers. Traditionally, mobile network operators (MNOs) have dominated connectivity management by offering connection to their proprietary networks. Mobile virtual network operators (MVNOs) disrupt this model by integrating connectivity with the cloud and lowering costs for mobile connectivity. The value of this business model has recently been recognized by connectivity protocol developer Semtech with its $1.2 billion acquisition of MVNO Sierra Wireless. MVNOs, including Sierra Wireless, differentiate with eSIM products incorporated into their hardware. eSIM has not gained widespread traction yet due to a lack of standards and low support from carriers. In particular, cellular networks such as NB-IoT do not work with most eSIMs on the market due to misalignment with the definitive Global System for Mobile Communications Association standard. We believe that improved standards will add value to MVNOs when competing against MNOs.

7: "Updated Worldwide Private 4G/5G Network Market Insights from 1H23 Publicly Announced Contracts," IDC, August 3, 2023.

eSIM startups are the top-performing startups in IoT hardware. Automotive is currently the most attractive market for this product, and improving connectivity regulations and LPWAN development should encourage further standardization. In Q2, iSIM innovator Kigen raised a $20.0 million Series B from its corporate parents SoftBank and Arm, demonstrating the opportunity in scaling its technology along with Arm CPUs. In Q3, eSIM startup Teal Communications announced a reseller agreement with T-Mobile, enabling the company to offer competitive rates on 5G connectivity services for T-Mobile's network. Teal has found promising markets in vehicles including automotive and drones. These companies compete based on the number of carriers they integrate with and the network types they offer access to, especially 5G and LPWA. We believe these companies can choose to raise capital to develop an MVNO product or pursue acquisitions by MVNO leaders.

Risks and considerations

Active incumbents: Startups in IoT networking must compete with network behemoths that invest heavily in research & development (R&D). Cisco focuses heavily on IoT connectivity and has the scale to develop global networks. Cisco has maintained the pricing power of its networking equipment, with more than 60% gross margins over the last decade because of high switching costs and risk aversion among network operators. Further, it has shifted to a subscription model that locks customers into three-, five-, or seven-year packages, including security and analytics platforms. For this reason, emerging networking players may need to compete on cost and manage capital across a long adoption cycle.

Execution risk: Developing IoT network infrastructure can require significant capital investment with uncertain payback periods. Low-power networks require either significant capital outlays to ensure quality of service or channel partnerships that risk compressing margins. Helium's low-power-network growth has leveled off after the value of its cryptocurrency rewards diminished, as outlined in our analyst note on Decentralized Physical Infrastructure Networks. Satellite fleets must forecast how much capacity they can offer while ensuring quality of service despite signal interference or unexpected traffic. Satellite deployments are inherently risky as customers may require expensive pilot projects to be completed before they can generate revenues.

5G faces hurdles to widespread IoT exposure: After COVID-19 delayed some 5G rollouts for up to 18 months, the US Federal Aviation Administration forced a pause of carrier projects near airports due to safety concerns. While those concerns have been alleviated, mass deployment of massive Machine Type Communications (mMTC), the 5G protocol best suited for IoT, was unlikely to be commercialized until 2025 based on the timeline for 3GPP Release 18, which is now likely to be finalized in Q1 2024. Cohere Technologies, Siklu, and Blue Danube will benefit from a rapid 5G rollout and may have to pivot toward private network developments if there are barriers to public 5G deployment.

Software

Overview

IoT software includes platforms that are used throughout the IoT value chain to process data from edge devices through to the cloud and applications. IoT software platforms are necessary for use cases including connectivity and message routing, device management and device registry, data management and storage, analytics, and application enablement.

In some cases, software is packaged with devices, but most commonly, platforms are selected to sit atop a variety of device types and connectivity solutions.

The subsegments within IoT software include:

Edge platforms: These are software platforms that manage devices as well as the collection of data at the edge. Commonly, these platforms create digital twins of edge assets that can be managed remotely. This subsegment also includes platforms that connect directly to devices without intermediate gateways. Technologies in this subsegment include universal platforms, edge computing, edge AI, and digital twins.

Middleware: These are software platforms sitting on the IT side of the network gateway that analyze IoT data and communicate it to cloud networks. Technologies in this subsegment include cloud services, fleet analytics, and connectivity software.

Application layer: Software-as-a-service (SaaS) applications for IoT data visualization and analytics built on top of IoT platforms, including application enablement for niche use cases, IoT web applications, relational databases, and augmented reality and virtual reality software.

IoT security: This involves platforms that improve the security of IoT devices, excluding software installed on the device itself. These platforms tend to assign identities to IoT devices and encrypt the communications between devices, central platforms, and the cloud. Technologies in this subsegment include identity access governance, encryption, and IoT/operational technology (OT) threat detection.

Industry drivers

Enterprises requiring advanced analytics from their IoT devices: IoT software is bolstered by the need for enterprises to extract meaningful insights from their sensor data. Enterprises are unlikely to deploy networks of IoT devices without advanced analytic capabilities.

Improvement in AI & machine learning (ML) algorithms enabling AI computing at edge: Edge-based AI & ML are enabled by the low cost of cloud computing and improvements in both software and the efficiency of ML algorithms, in part owing to open-source ecosystems. These developments can be leveraged to make 10x the improvements to IoT value propositions. Recent scientific developments have enabled compression of ML algorithms to the point they can run on common IoT processors.

Critical infrastructure cyberattacks: According to a survey of OT professionals in critical industries like utilities and healthcare, 75% of OT organizations experienced at least one digital attack in the last year.[8] In March 2022, the Biden administration signed the Cyber Incident Reporting for Critical Infrastructure Act of 2022 (CIRCIA), requiring entities in 16 industries to report some cyber incidents within 72 hours and encouraging organizations to adopt incident response services to quickly identify breaches.

8: "2023 State of Operational Technology and Cybersecurity Report," Fortinet, May 24, 2023

Market size

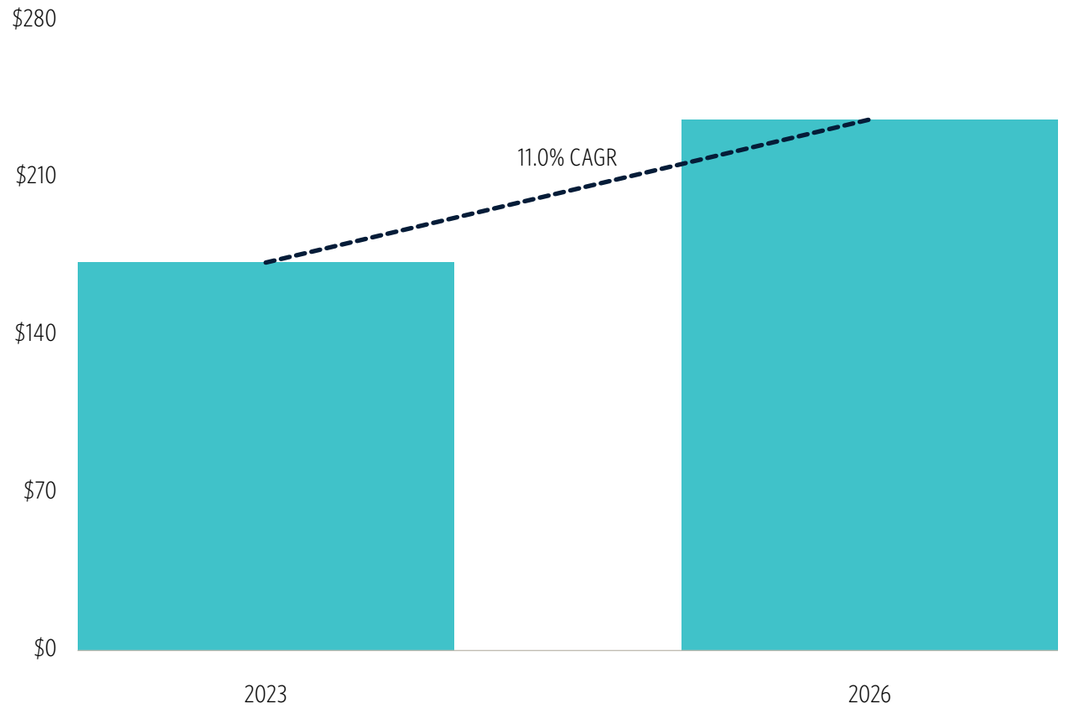
We estimate the IoT software market will reach $136.6 billion in 2023, with much of this spending driven by the monitoring software provided by industrial automation incumbents and cloud analytics. We expect software to slightly increase as a share of the total market, growing at a 12.5% CAGR to 2024. This forecast is based on our estimate of 19.6% of IoT spending flowing to software, which should increase slightly as more advanced analytics and open-source middleware solutions are applied to existing device fleets.

Business model

IoT software is typically delivered through a SaaS business model. Given the number of important functions for IoT platforms, there is significant upsell potential. Vendors can offer modules such as edge devices, cloud connectivity, cloud analytics, and application enablement. Edge device management is typically the base platform atop which additional features can be layered. When application programming interfaces (APIs) are enabled, typical API request pricing can be offered.

Some IoT startups have identified the need for a low-cost solution for enterprises experimenting with IoT and have launched a near-"freemium" (a portmanteau of the words "free" and "premium") model in which a low-cost platform is used during a trial phase that can be upsold to an enterprise license after proof of concept. Ideally, enterprise licenses will scale with both the size of the customer organization and number of devices deployed.

IoT software market size estimate ($B)*



Source: PitchBook Emerging Tech Research • Geography: Global • *As of June 30, 2023

Opportunities

Data integration

Enterprise IoT systems create diverse data silos that can benefit modern data integration tools. As enterprises focus on business value over blindly deploying IoT devices, they find value in combining data streams from multiple systems to analyze sensor data. Real-time correlation of data points can enable rapid response to IoT alerts, though it requires event-based integration. Event-based processing executes calculations on real-time data streams and benefits from the popularity of open-source protocols including Apache Kafka and Pulsar. According to IDC, $3.0 billion will be spent on IoT event stream processing in 2023, the second-largest subcategory behind IT messaging.[9] We expect high growth in this emerging segment given the focus of event streaming startups on IoT data.

We track IoT as a core use case for data integration platforms including Striim, Ably, InfluxData, and Acceldata. In 2021, Acceldata and Ably each achieved over 6.0x valuation step-ups. The two largest deals we tracked in IoT middleware in 2023 were for data integration startups. In Q1, InfluxData raised an $81.0 million Series E led by Princeville Capital and Citi Ventures. The company's InfluxDB product is a popular time series database and is leading to an open-source product. The company features IoT-focused customers including Nest, PTC, and Siemens, thus demonstrating the scale that can be achieved by selling software to device original equipment manufacturers (OEMs). Much as information security companies have scaled by including IoT devices as a data stream, so, too, can data integration startups improve the aggregation of device data from across communication protocols while building large businesses similar to Confluent.

IoT/OT security

The IoT/OT security market offers sufficient enterprise budgets for startups to focus on critical infrastructure. ABI Research estimates that over 50% of information security (infosec) spending originates from users with critical infrastructure, led by defense-related organizations with around 15% of the market overall.[10] This spending accrues to a range of solutions including managed services and noninfrastructure software such as identity management and firewalls. More narrowly, in device-specific software, we estimate the IoT/OT security market will reach $5.6 billion in 2023. Billion-dollar markets exist across OT-specific segments of device security, network & communication security, and visibility & risk assessment.

IoT/OT security startup funding has slowed since the boom of 2021, yet device-focused companies with critical infrastructure applications continue to achieve valuation growth. In Q2, Shift5 extended its Series B at a 3.9x valuation step-up, resulting in a $370.0 million post-money valuation. Shift5 directly supports the US government with defense of cyberphysical systems such as aviation and weapons systems with edge-based analytics of OT data. This approach differs from most IoT security vendors, which require data to be routed to IT systems for analysis. This deal was justified by a doubling of the company's annual recurring revenue (ARR), which the company disclosed exceeded $10.0 million in 2022, featuring strategic investments from Booz Allen Hamilton and JetBlue. The deal indicates that critical infrastructure security is a priority for federal contractors and transportation leaders. There is an IPO pipeline of IoT/OT security leaders including Dragos, Armis, Claroty, Nozomi Networks, and Axonius, pending improved market conditions.

9: "Worldwide Event Stream Processing Software Forecast, 2023–2027," IDC, August 31, 2023

10: "With COVID-19 behind, New Cybersecurity Spend in Critical Infrastructure to Reach US$236 Billion by 2027," ABI Research, May 16, 2023.

Edge AI compression

Compared to leading AI inference engines, startups are achieving competitive results for edge AI efficiency. Recent benchmark results found that Krai, Plumerai, and Syntiant can achieve competitive results training feed-forward binarized neural networks and 8-bit deep learning models when compared to leading inference engines from Google's TensorFlow, chip incumbent STMicroelectronics, and devicemaker Syntiant.[11] The study focused on the commonly benchmarked computer vision model MobileNetV2 and drew on publicly available test results. These startup platforms optimize AI training processes for edge architectures, manipulating the convolutions within deep learning models to minimize memory usage and processing time without pruning the layers of the model itself. These startups' outstanding results and interoperable platform approaches are enabling partnerships with leading chipmakers.

Chipmakers are partnering with startups to bring specialized software to their hardware platforms. In Q2, voice recognition chipmaker Syntiant announced a partnership with microelectronic microphone maker TDK for always-on speech recognition. Syntiant is a leading chip supplier to Amazon's Alexa hardware products, suggesting that the company may be able to scale across more consumer electronic devicemakers. Edge Impulse has continued to grow its partner community in 2023 with MemryX and BrainChip, adding to an impressive roster of cutting-edge chipmakers. To make the latest innovations in AI processing accessible on all devices, new stacks of inference engines and application-specific processors are likely to capture market share in specific use cases.

11: "Inference: Tiny v1.1 results," ML Commons, June 27, 2023

Risks and considerations

Crowded and fragmented platform market: The wide variety of IoT platforms offered by incumbents makes scaling difficult. Currently, there are least 600 such software platforms. Incumbents have developed leading solutions for key IoT platform functions including security, connectivity, middleware, and analytics. Application enablement and user interface (UI) are relatively uncrowded spaces, though these features might not be significant value drivers compared with security, connectivity, and middleware. Analytics startups are forced to partner with incumbent cloud providers. At the same time, these incumbents are developing competing sets of functionality, thereby creating conflicts of interest within their marketplaces. Holistic IoT platforms have faced low valuation growth between rounds and down rounds.

Software vendors face competition from manufacturer software packages: Hardware vendors increasingly seek to sell their products as a service, thus potentially displacing third-party software platforms. We believe platforms are necessary across large-scale deployments, but specific use cases may not require them.

Vendors claim to provide IoT security: Device vendors are increasingly recognizing the security problem and are developing solutions internally and through M&A. IoT incumbents have forayed into the IoT security space, which may force IoT startups to sell before achieving scale. Microsoft has developed end-to-end security on its Azure Sphere platform, which we believe is competitive in the market. Further, Cisco has acquired Sentryo, thus further enhancing its ability to include security as a component in its networking subscription services. On the device side, Siemens has escalated its vulnerability disclosure and patching programs, thereby limiting the need for third-party vendors to conduct security scans.

Industrial IoT

Overview

Industrial IoT (IIoT) technologies, collectively referred to as "Industry 4.0," allow for the digital and smart transformation of capital-intensive industries including manufacturing, logistics, transportation, and oil & gas production. Sensor technologies, Big Data, analytics, and other technologies are used to monitor and diagnose manufacturing machinery and equipment, supply chain, and safety operations. This allows for predictive maintenance, demand forecasting, improved productivity, and better efficiencies across the entire value chains of industrial companies.

Subsegments within IIoT include:

Manufacturing & supply chain: Devices that enable predictive maintenance of industrial equipment and asset tracking of inventory along the supply chain.

Energy & utilities: Devices and sensors that measure power generation and usage, including oil & gas extraction monitoring.

Agriculture: Devices that monitor field conditions for agricultural planning.

Industry drivers

The United States has experienced a striking surge in construction spending for manufacturing facilities, which has doubled since the end of 2021.[12] The Infrastructure Investment and Jobs Act (IIJA), the Inflation Reduction Act (IRA), and the CHIPS and Science Act each provided direct funding and tax incentives for public and private manufacturing construction.

The rising volume of equipment data from programmable logic controllers, enterprise resource planning systems, and industrial sensors has created a need for companies to organize it.

Global supply chains increasingly pressure companies to maintain visibility along networks of manufacturers and distributors to avoid "retail shrinkage," or loss of inventory due to shoplifting, theft, or administrative errors.

Market size

We estimate the industrial IoT market will reach $370.1 billion and grow at a 10.7% CAGR to $501.4 billion in 2026. We have revised our market size upward based on improved data in manufacturing equipment yet have also revised downward growth expectations for the industry given global economic uncertainty and the slow pace of US manufacturing reshoring. Manufacturing facilities

12: "Unpacking the Boom in U.S. Construction of Manufacturing Facilities," US Department of the Treasury, June 27, 2023

management and process automation remain two of the top 10 largest use cases in IoT and are projected to maintain double-digit growth through the decade, creating a large and high-growth market for startups to address. Energy & utilities has become the fastest-growing subsegment in IoT based on high growth in electric vehicle (EV) charging and smart energy meters. After low deal values in the space, this inflection may open new opportunities for energy management software.

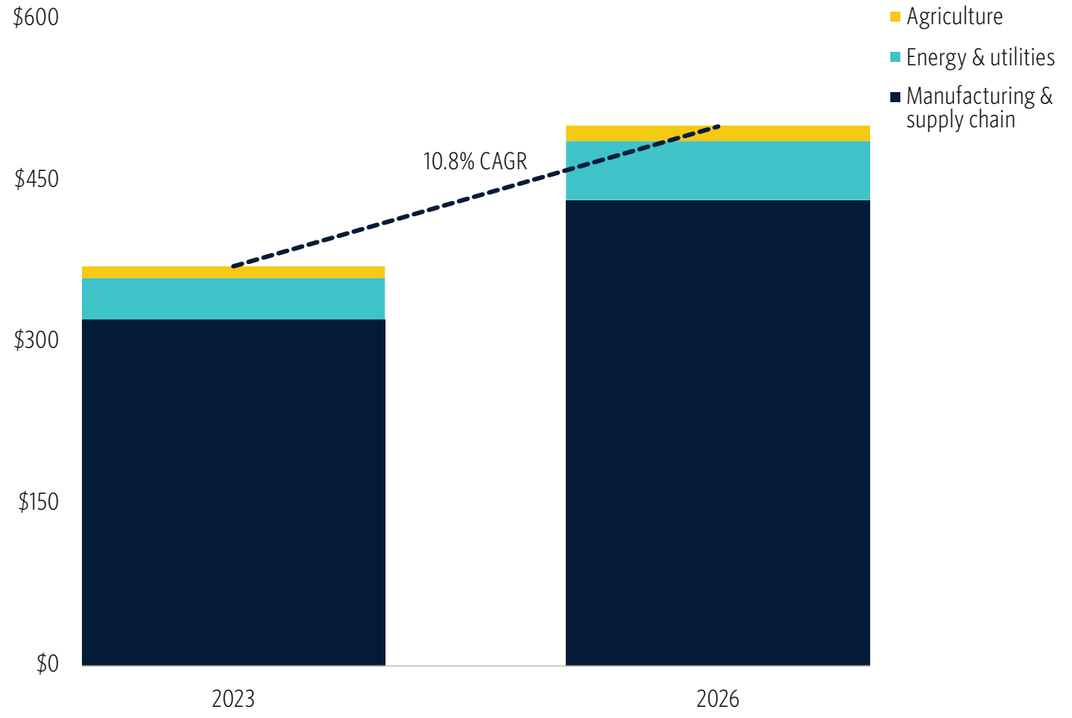
Business model

Industrial IoT devices can be packaged to collect data from specific industrial equipment and processes. Revenue is generated through the sale of these devices, along with associated services like installation and maintenance.

Machine-as-a-Service (MaaS) is a business model in which companies offer machinery or equipment to customers as a service rather than a one-time product purchase. The recurring revenues in a MaaS model are generated based on the uptime or usage of these machines. Customers pay on an ongoing basis, typically through subscription or usage-based fees, which ensures that they pay only for the time the machines are operational. This model benefits both customers, who enjoy reduced upfront costs, and providers, which then have a steady stream of income.

Platform-as-a-service (PaaS) models allow industrial clients to build and deploy their IoT applications on vendor infrastructure. These platforms often come with tools for data management, analytics, and application development.

Industrial IoT (IIoT) market size estimate ($B)*



Source: PitchBook Emerging Tech Research • Geography: Global • *As of June 30, 2023

Opportunities

Predictive maintenance

Oil & gas startups are producing the highest valuation growth in predictive maintenance. In Q2, Accenture acquired industrial IoT startup Flutura to improve energy efficiency. Flutura's customer references focus on oil & gas including Shell, Hess, Aramco, and Delek. IoT analytics can help these customers achieve their emissions targets. Flutura conducts statistical analysis based on physics, behavioral analysis, and machine learning based on time series. While this approach is common, optimizing for environmental goals can help startups stand out. In Q3, oil & gas strategic investors Chevron Technology Ventures and Delek US Holdings joined specialist VC firm Momenta Ventures in a Series A1 for APERIO, which improves data quality for asset monitoring. Environmental goals require better technology for oil majors, offering the best opportunities for equipment maintenance contracts.

Smart manufacturing

We expect edge AI will power manufacturing automation in the future. Most machines remain unconnected to the internet and may require embedded AI capabilities to benefit from analytics advancements. Further, it is clearly the top use case for edge computing overall.[13] Penetration of neural networks in machine vision remains low, with industry estimates pinning the share of machine vision devices with embedded AI at under 10%—though this percentage is growing quickly as industrial electronics incorporate more AI processing chips.[14] We believe that over 10% of machine vision devices will incorporate edge AI capabilities by 2024 and power a $3.9 billion market for AI embedded manufacturing devices led by machine vision cameras.

Government incentives offer opportunities for early-stage startups to develop new approaches to manufacturing. In Q3, Pico MES announced a Series A led by Bosch Ventures and joined by Counterpart Ventures and Momenta. The company cites doubling in new factory construction spending in the US as a catalyst to build a manufacturing execution system for small manufacturers. The company's no-code platform can be configured to a variety of manufacturing settings including modular factories, which can lower the costs of deployment. Also in Q3, Raven raised a Series A at a $143.8 million pre-money valuation to develop data visualizations for factory floors that can be easily monitored on tablets by front-line staff. The company is exploring AI integrations yet doesn't explicitly generate content with AI. Both startups indicate that high growth is ahead of advanced manufacturing startups.

Risks and considerations

Limited product-market fit with enterprises: Architectural complexity among disparate machineries makes implementing new IoT components and protocols especially difficult and time consuming. Many companies that are adopting IoT strategies remain in "pilot" mode. Although international standards such as ISA-95 have been developed to help create automated interfaces across control systems and enterprises, successful deployments and use cases still require a patchwork of custom software integrations and long sales cycles to persuade both IT and OT stakeholders.

13: "The Emerging Edges: What, Where, When?" Webinar by Omdia, Clifford Grossner, February 2, 2021.
14: "Artificial Intelligence for Edge Devices – 2020 Report," Omdia, Anand Joshi, May 22, 2020.

Incumbents dominate the market and have wide moats: Currently, the major players in this space are the large conglomerates such as GE or Siemens that dominate the market. Additionally, collaboration among incumbents is increasing, which may crowd out startups in this space. For example, Cisco has integrated its networking capabilities with GE's Predix software and Rockwell Automation's devices. Siemens has partnered with IBM and Alibaba Cloud. Microsoft has a partnership with Schneider Electric and AWS is also active in expanding its presence in industrial. The result of such partnerships may bridge the gap between controls and analytics.

Connected buildings

Overview

Providers in the connected buildings space develop sensors that enhance the built environment, including both building operations and occupant experience. We include both commercial and residential buildings in this segment because emerging technologies can be applied in both use cases. Incumbents provide sensors to both commercial and residential markets, although startups have typically focused on either consumer or commercial opportunities. We see startups moving further upstream to develop solutions that can apply to both commercial and consumer spaces.

Subsegments in connected buildings include:

Consumer: IoT technologies used in consumer environments including homes and multifamily buildings. Technologies in this subsegment include hardware, platforms, connectivity, and multifamily automation.

Connected commercial real estate: Sensors, connectivity and automated processes that control building operations such as lighting, HVAC, appliances, or security. These technologies help building owners, operators, and occupants improve energy efficiency, physical security, thermal comfort, and air quality. Technologies in this subsegment include controls and sensors.

Smart retail technologies: Sensor systems that enhance the management and customer experience of brick-and-mortar stores. Technologies in this subsegment include inventory loss prevention, customer engagement, and smart shelves & checkout.

Industry drivers

Installation of smart home systems in new buildings: Home builders and commercial property developers are adopting smart home and multifamily automation as upsell opportunities in new construction. Pre-installed smart home systems are becoming the default in multifamily and single-family homes, with 27% of all multifamily units having a smart device installed by the landlord as of February 2022.[15]

Smart speaker adoption has reached scale: In 2019, smart speaker unit sales grew 47.4% to 127.1 million and remained resilient during COVID-19 as Alexa and Google Assistant have become mainstream. Demand for smart products among consumers is high, and new innovations are being adopted at scale.

Shifting mobility landscape: The rapidly changing mobility landscape is driving demand for connectivity solutions and cloud access to deliver information such as weather conditions, safety hazards, or traffic delays. Mobile network operators led by NTT DoCoMo and Vodafone are enabling this growth by constructing LTE and 5G terminals on roadway infrastructure. Additionally, an increasing number of OEMs, including, most recently, Volkswagen, are embedding dedicated short-range communications (DSRC) within automotive designs.

15: "27% of Multi-Dwelling Unit (MDU) Residents Have a Smart Device Provided by Their Landlord or Property Owner," Parks Associates, February 1, 2022.

Market size

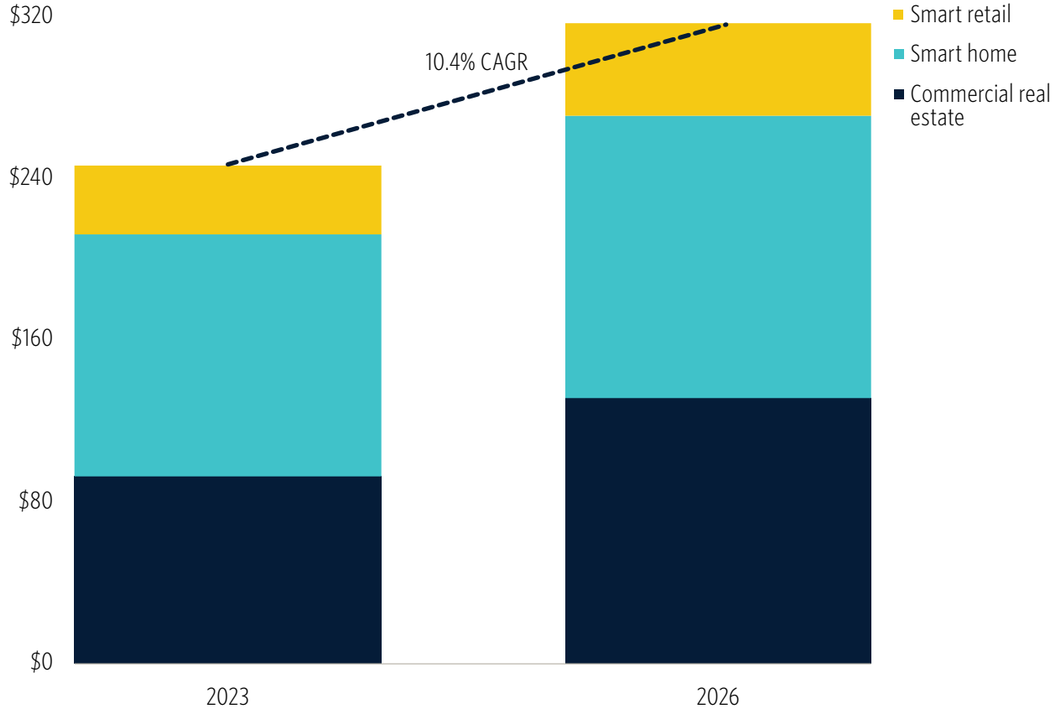
We estimate the connected buildings market will reach $246.8 billion in 2023 and will grow more slowly than the IoT market at a 10.4% CAGR to $317.2 billion in 2026. We have revised this estimate downward based on underperformance in smart home. Commercial real estate will grow more quickly than smart home at a 13.6% CAGR to become nearly the same size by 2027. Retail has also recovered from pandemic lows to invest in customer engagement via digital technologies. The highest volume of IoT device shipments comes from electronic shelf labels and indoor signage.

Business model

Smart building technologies are sold as both units and solutions. Unit sales refer to devices that are sold as retrofits to legacy systems, including smart thermostats and connected lights. These unit sales can have software subscription options, which can generate recurring revenue. We believe this razor and blades model is becoming more common in smart home and is important for the sustainability of IoT business models. Solution sales refer to long-term contracts that guarantee savings and can integrate a variety of technologies to achieve a specific economic outcome.

Some startups are bundling home automation technologies for multifamily installations. This business model has been proven by Control4, which packages home automation technologies including lighting, audio, video, climate control, intercom, and security for home builders to include in new buildings. This bundling reduces the friction of direct-to-consumer (D2C) business models and increases the average customer value, which is crucial for hardware companies.

Security operations market size estimate ($B)*



Source: PitchBook Emerging Tech Research • Geography: Global • *As of June 30, 2023

Opportunities

Building twins

Smart buildings stand out as a leading use case for digital twin software. IoT software and industrial IoT platforms have generally struggled to raise funding at higher valuations during the market downturn. Notable exceptions emerged in the building-monitoring market. Europe-based construction analytics startups Disperse and Modulous raised rounds exceeding $10 million during H2 2022. Modulous creates digital twins of construction sites based on prefabricated materials, incorporating visual and structural data. Disperse analyzes construction projects using data visualization. It raised $16.0 million in a round led by urban-tech investor 2150. 5x5 Technologies raised convertible debt to pursue an adjacent space of critical infrastructure monitoring. Other digital twin startups in manufacturing and healthcare failed to achieve the same deal sizes, showing the gap in the market for startup solutions in building management.

Among startups in earlier stages, T2D2 raised an angel round to create digital twins of buildings with drone cameras. The company spun out of an AI research team at engineering firm Thornton Tomasetti, where founder Badri Hiriyur was director of AI. T2D2 has a proprietary dataset of 300,000 building images, which can be used to train drones to detect decay in a wide range of buildings and offer digital twins of buildings that identify flaws and assist with maintenance. The software integrated with Autodesk's Construction Cloud in Q3 2022. The company forecast $600,000 in 2022 revenue in a public pitch based on partnerships with governments, a university, and a sports team, and it closed a $350,000 angel round in January 2023.

Multifamily access management

Major multifamily real estate developers shifted to smart home installations during the pandemic for remote tours and remote access control. This process has historically been a patchwork assembly of multiple devices, and 15 of the top 20 multifamily owners in the US have adopted software from formerly VC-backed SmartRent for building access, parking management, and comfort controls.[16] At the residential level, excluding smart speakers, a smart lock tends to be the first smart home device that homeowners purchase.[17] Smart locks have been a leading driver of deal activity in smart home, with the latest megadeal stemming from Fortune Brands Innovations' acquisition of ASSA ABLOY's smart lock business as part of an $800.0 million deal in Q2 2023.

Numerous startups are developing smart locks to take advantage of this trend. In Q2 2023, ŌURA acquired biometric access startup Proxy to bring building access together with personal health in a single biometric. In VC, Operto raised a $25.0 million Series B to enable keyless access management for rental properties, even in a challenged macroeconomic environment for real estate. The company added the former head of Airbnb's commercial team as a board member. Level Home raised $50.0 million in debt from strategic investor Cox Communications in December 2022, demonstrating continued appetite for new technology after SmartRent's tepid performance on public markets.

16: "2023 SmartRent Earnings Deck," SmartRent, August 2023.
17: "Survey Says: The Future of Smart Homes and Appliances Has Arrived," Parks Associates, October 21, 2021.

In-store contextualized marketing and cashierless checkout

Retail experiences have already benefited from novel payment technologies, and startups can bring improved in-store marketing experiences to build brand loyalty and remove the need for in-person sales. Location-based IoT sensors, for example, allow companies to push personalized offerings and discounts to shoppers as soon as they enter a store. VC-backed Mojix has developed a digital assistant for shoppers to create a personalized shopping experience. Instacart's $350.0 million acquisition of smart shopping cart startup Caper demonstrates that shopping carts can provide new communication channels with customers while facilitating cashierless checkout. We estimate the retail customer communication device market has already reached $9.1 billion globally in 2023 and will grow quickly in 2024.

Smart home integrations with open standards

Smart home giants are increasing the interoperability of their devices by using open network protocols. The Matter smart home protocol is a connectivity protocol supported by a consortium of leading smart home device vendors including Amazon, Google, Apple, and Samsung, as well as the Connectivity Standards Alliance, formerly known as the Zigbee Alliance. The protocol launched in 2022 and now supports some initial devices that have been designed for compatibility. This protocol promises to alleviate the challenges that homeowners have faced when integrating devices from different vendors. Startups that support the protocol can scale. Brilliant (Household Appliances) is well poised to scale after raising VC in Q2 and configuring its devices to support the protocol.

At the vendor level, Amazon has created an open ecosystem for Alexa that allows third parties to embed Alexa into their operating systems. For example, LG smart refrigerators and TVs are being built with Alexa voice control. Its "Wi-Fi Simple Setup" shares wifi credentials with compatible smart devices and connects new devices within 30 seconds. Startups have found Alexa integrations to be popular with customers and powerful for developers to build new features. Alexa's team at Amazon has promoted startups including smart shower startup Orbital Systems, hearing aid startup Cognixion, and assistive robot Labrador Systems. Each of these startups has the opportunity to create a category and take advantage of new conversational AI capabilities.

Risks and considerations

Technological fragmentation leading to poor user experience (UX): There are at least six major smart building standards in varying states of alignment, with an additional 22 building automation standards, thus leading to difficulties in integrating various disparate devices, network systems, and protocols. This fragmentation complicates the integration of smart devices. Compounding this fragmentation, leading vendors for common smart building technologies have different software systems, thereby both limiting the value proposition of a connected building and increasing sales friction. Device manufacturers with proprietary technologies have little incentive to collaborate with others to develop a standardized architecture, thus causing interoperability difficulties for customers. Smart home platforms are better designed to integrate third-party components, which is highlighted by numerous early-stage "universal control" startups including Yonomi and Yeti, and VC exits including SmartRent, SmartThings, Tuya Smart, and Wink. The relative lack of highly funded connected commercial real estate startups suggests that the commercial space problem may be more difficult to overcome.

Mounting security and privacy concerns: The ever-increasing connectivity of home and buildings comes with proportionally increasing security vulnerabilities. These cybersecurity risks, along with privacy concerns, have heightened in recent years and will remain an ongoing struggle for companies in this space. Furthermore, governments will play a role in the cybersecurity of consumer IoT devices—for example, US federal legislation called the Cyber Shield Act, which proposes a voluntary cybersecurity certification program for smart home devices. Several similar bills have been introduced at the state level and in Europe. These developments can lead to burdensome compliance processes and risks of fines and penalties for manufacturers and service providers.

Industry consolidation: The emerging Matter standard promises to favor incumbents, thus lowering the value of startups with interoperability solutions. The Matter smart home standard unites devices from multiple manufacturers with a common networking signal under the Zigbee protocol. This shared protocol changes the patchwork of frequencies previously used by manufacturers that made their devices incompatible with competitors'. This standard was released by the Connectivity Standards Alliance in October 2022. Contributors to the standard include Amazon, Apple, Google, LG, and Samsung, which all rank among the market leaders in smart home device shipments. The standard applies retroactively to most existing devices, thereby enhancing the value of legacy hardware. We have tracked only four exits for smart home startups in H1—all with undisclosed exit value—suggesting there are limited paths to scale for startups.

Connected services

Overview

Connected services refers to IoT technology that address basic consumer and municipal needs. Subsegments in this category include:

Smart cities: The use of devices to improve urban governance and quality of life. Technologies in this subsegment include smart streets & lighting, smart infrastructure, digital signage, and smart city platforms.

Smart healthcare: Devices that track consumer health conditions and transmit data for medical review both in and out of hospitals. Technologies in this subsegment include biometrics & wearables, remote patient monitoring, and smart hospital devices.

Connected mobility: Sensors and connectivity devices that enable communication between vehicles and the internet. While vehicles are a consumer good, the connectivity that empowers them will increasingly be distributed as a service through road infrastructure and new vehicle design. Technologies in this subsegment include autonomous vehicle connectivity, shared mobility, fleet management, and connected car.

Industry drivers

Local and national governments have increased focus on sustainability and environmental impacts, and urban centers continue to become more densely populated, with 68% of the world's population expected to live in urban centers by 2050, up from 56.2% in 2020.[18] Smart cities technologies have become a cornerstone of municipal efforts to handle population increases.

The rapidly changing mobility landscape is driving demand for connectivity solutions and cloud access to deliver information such as weather conditions, safety hazards, or traffic delays. Mobile network operators are enabling this growth by constructing LTE and 5G terminals on roadway infrastructure. Additionally, an increasing number of OEMs are embedding DSRC within automotive designs.

Automakers are investing heavily in connected car technology. These investments will fuel startup growth in connected vehicle technology.

18: "World Urbanization Projects," United Nations Department of Economic and Social Affairs, May 16, 2018.

Market size

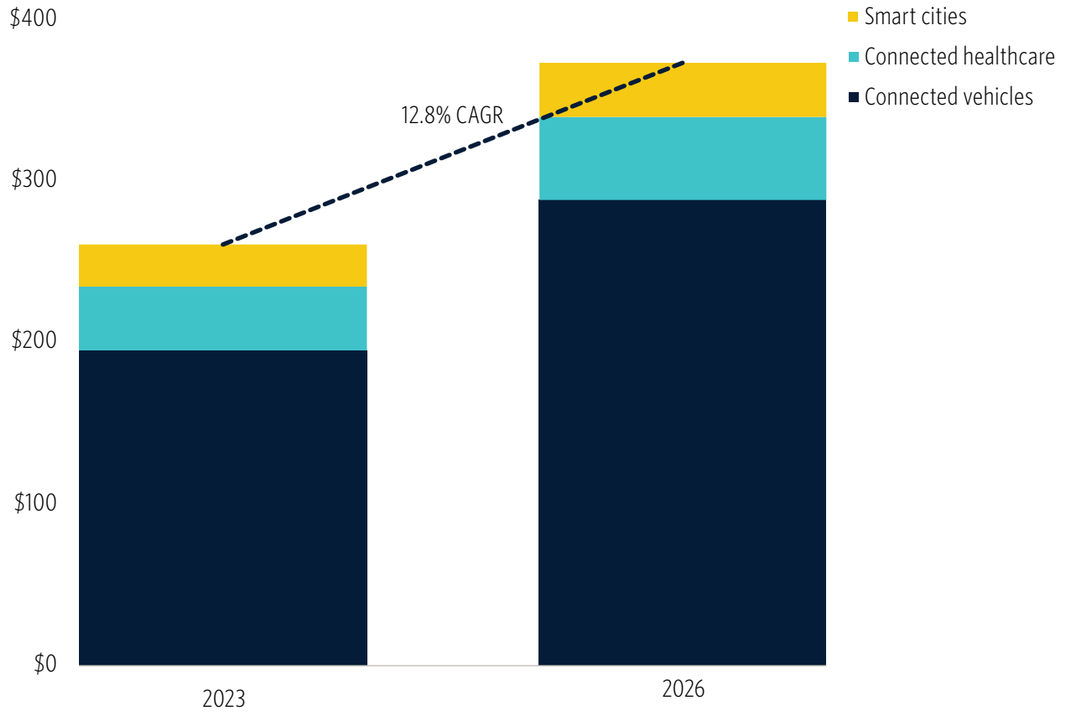
We estimate the connected services market reached $260.7 billion in 2023 and forecast it to grow at a 12.8% CAGR to $373.3 billion in 2026. This market is led by connected vehicles, which reached $177.7 billion in 2022 based on commercial and consumer vehicle sales. Smart cities has slowed to the lowest-growing subsegment in IoT. Healthcare had demand pulled forward by the pandemic and has a relatively lower growth outlook at a 10.4% CAGR to a $51.6 billion market in 2026. Relatively weak growth in fitness trackers and watches explains this muted growth, though medication management and hospital hygiene monitoring have achieved high growth.

Business model

Smart cities companies utilize a variety of business models. Equipment vendors earn gross margins on the sale of each hardware unit or adopt a "build, operate, and manage" model in which providers receive upfront and recurring revenues. Sales are typically structured as partnerships with local and national governments, businesses, and existing infrastructure providers.

Vehicle connectivity companies sell services based on communication with networks, other vehicles, and infrastructure. Fleet management companies provide mobile workforce platforms and solutions for service-based businesses operating fleets, such as UPS and long-haul trucking. Services include tracking, routing, and scheduling, as well as monitoring fuel consumption and driver behavior. Providers can also ensure compliance with policies, monitor diagnostics, document damages, update inspections, and schedule repairs and services.

Connected services market size estimate ($B)*



Source: PitchBook Emerging Tech Research • Geography: Global • *As of June 30, 2023

Fleet management solutions generally charge subscription fees for SaaS solutions or other transactional services often paired with in-vehicle monitoring hardware. Connectivity suppliers monetize by providing systems and components to major OEMs.

Connected healthcare companies monetize by selling their products and services to healthcare providers and payers either through a B2B2C model or D2C. Both hardware and software could be sold through a one-time purchase or through a software-as-a-service model.

Opportunities

Development operations (DevOps) stack for car computing and connectivity

Automakers are disintermediating their software development and are producing more software in house. Conventionally, automakers sourced software for each of the components procured from suppliers. These components can be supplanted with a central software brain in the form of a high-performance computer within the vehicle, connecting all components together with a common logic. Volkswagen, Toyota, and Continental are leading innovators in this area. These automakers are investing in software development teams to build applications on top of the sensors and displays being deployed in their vehicles. To achieve the software-defined vehicle vision, developers must be able to treat the car like a cloud application, with microservices architectures updated continuously and built-in cybersecurity.

Apex AI and CerebrumX have translated VC investment to significant commercial partnerships. In Q2, automotive audio company Pioneer announced an investment in CerebrumX and a strategic collaboration to jointly expand their mobility services business globally. Along with this announcement, CerebrumX reconfigured its proprietary Augmented Deep Learning Platform (ADLP) to integrate data from smartphone applications and other aftermarket devices such as dongles and dashcams for better infotainment experiences. Apex.AI announced partnerships with Krone and Lemken for autonomous agricultural vehicles and MOIA for passenger management in autonomous vehicles. This shows that third-party software platform can be essential for the future of connected vehicles.

At the early stage, DIMO raised a $9.0 million seed round led by Coinfund. The Web3 startup uses cryptocurrency tokens to reward drivers for sharing their data and offers an application ecosystem for connected car data for vehicle health, vehicle-to-vehicle (V2V) connectivity, and automotive documents including title and registration. This incentive-based approach has proven successful in gaining user adoption for Helium in IoT data sharing. DIMO leverages Helium's wireless protocol for data transfer, which incorporates both long-range (LoRa) and 5G connectivity yet remains nascent in terms of coverage. The startup offers the potential to share vehicle data outside of conventional telecommunications companies yet will require a more developed network infrastructure to fulfill its promise.

Remote patient monitoring for infants and older adults

Babies and older adults are at an elevated risk of hospitalization and can benefit from continuous monitoring from their supervisors. Half of older adults have broadband connections in their homes in the US, and insurance companies are incentivizing the use of connected healthcare technology, such as IoT sensors that can detect deviations from baseline activity levels. This can reduce older adult living costs, as well as the need for routine checks from caretakers and older adult living staff. The space is beginning to reach scale, given the shift to telemedicine. In Q3 2021, Owlet

achieved a $1.0 billion valuation in its SPAC merger, an 18.6x MOIC. This valuation set a record for connected healthcare exits. The company enables remote monitoring of infants via a Smart Sock that measures heart rate. In older adult care, both K4Connect and Birdie have raised significant VC rounds. Top European investor Index Ventures led Birdie's Series A. We expect to see an exit at a similar scale to Owlet's in the senior care space.

Public safety

In smart cities, while environmental and health concerns generally receive more airtime, public safety remains the most economical use case. Outdoor surveillance is the top use case for smart cities; the area is estimated to ship $7.1 billion in devices in 2023—over 4x over any other use case. In Q2, Databuoy achieved a $20.0 million pre-money valuation in its Series A, the highest we have tracked in smart cities this year. The company brings new acoustic gunshot detection systems to market, which may be needed after public gunshot detection company SoundThinking (formerly Shotspotter) has faced technical product concerns yet retains a market cap over $200.0 million. SoundThinking has remained an active acquirer, buying outdoor surveillance company SafePointe in Q3 after the startup achieved $3.6 million in ARR. As smart cities growth in North America slows, this space will likely remain relevant as cities grapple with lean police forces.

Risks and considerations

Strong public criticisms regarding privacy: Smart cities rely primarily on aggregated and real-time data to provide useful functions such as analyzing street traffic or spotting hazards. However, this increased collection of data raises concerns related to personal privacy, excessive intrusion, and continuous surveillance, thereby increasing the possibility that public backlash could have an impact on the development of the industry. We expect privacy and social impact risks to be front and center for companies in this space, as well as a long-term hurdle.

Smart city and connected vehicle implementations require patience: The potential for new technologies to transform how cities operate and to provide benefits to communities is still in its infancy. The combination of multiple participants—including IoT companies, government officials, and service providers—several installation phases, and high upfront costs for even small smart city projects limit return on investment (ROI) over short time horizons.

Security a primary concern: Several issues contribute to the amplification of cyberthreats in smart city and V2V ecosystems, including lack of cryptographic measures, poor encryption key management, nonexistent secure device onboarding services, weaponized ML technologies by cyberattackers, poor understanding of social engineering, and lack of protection versus distributed denial-of-service (DDoS) attacks.

Appendix

Top VC-backed IoT companies by total VC raised to date*

Company	VC ($M) raised to date	Segment	Subsegment	IPO probability	M&A probability	No exit probability
Zenerate	$4,000.0	Connected buildings	Connected commercial real estate, smart building	6%	72%	22%
JD Digits	$2,127.9	Industrial IoT	Manufacturing & supply chain, IIoT platforms	N/A	N/A	N/A
Horizon Robotics	$1,900.0	IoT hardware	Chipsets, system on chip	N/A	N/A	N/A
WeRide	$1,422.0	Connected services	Connected mobility, autonomous vehicles	N/A	N/A	N/A
Face++	$1,258.0	Connected services	Smart cities, smart city platform	N/A	N/A	N/A
Securonix	$1,237.1	IoT software	IoT security, IoT security platforms	43%	55%	2%
SambaNova Systems	$1,136.6	IoT hardware	Chipsets, system on chip	61%	37%	2%
ESWIN Computing	$1,100.0	IoT hardware	Chipsets, system on chip	N/A	N/A	N/A
Tanium	$982.3	IoT software	IoT security, IoT security platforms	91%	4%	5%
Royole	$955.5	IoT hardware	Sensors & sensor systems, edge devices	N/A	N/A	N/A

Source: PitchBook • Geography: Global • *As of June 30, 2023

Note: Probability data based on PitchBook VC Exit Predictor methodology.

Top VC investors in IoT companies since 2017*

Investor	Deal count	Investor type
SOSV	99	VC
Alumni Ventures	67	VC
Intel Capital	63	CVC
Shenzhen Capital Group	57	VC
Walden International	54	VC
Hax	53	VC
Shunwei Capital	52	VC
IDG Capital	51	VC
Qualcomm Ventures	48	CVC
Oriza Holdings	44	VC

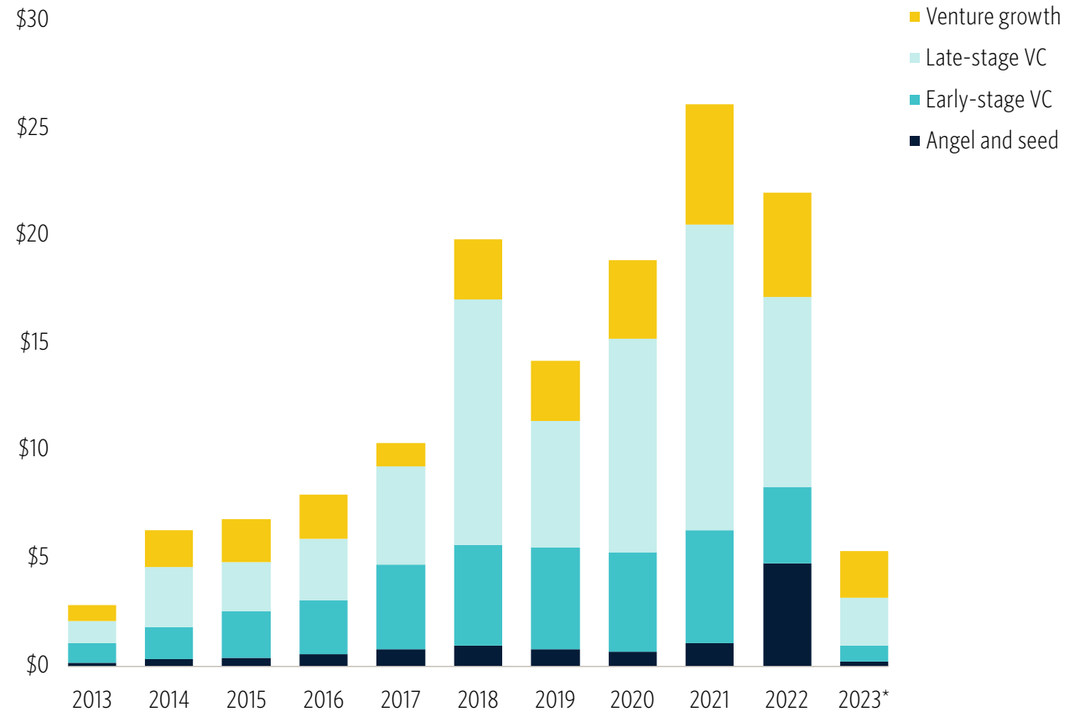
Source: PitchBook • Geography: Global • *As of June 30, 2023

Top strategic acquirers of IoT companies since 2017*

Acquirer	Deal count	Investor type
Bravas Group	13	PE-backed company
Wireless Logic	12	PE-backed company
HID Global	8	Corporation
Accenture	7	Corporation
Assa Abloy	6	Corporation
ARM	6	PE-backed company

Source: PitchBook • Geography: Global • *As of June 30, 2023

IoT VC deal value ($B) by stage



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