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Smarter devices and better standards are driving innovation for a more reliable, intelligent, and sustainable future.

The next generation of connected IoT

Key takeaways

- **Burgeoning demand for smart, connected devices in every area of work and life is transforming traditional industries and businesses into tech companies.**
- **Innovations in four enabling technologies – chips, connectivity, security, and artificial intelligence – are improving Internet of Things (IoT) devices and unlocking a broad spectrum of use cases.**
- **The next generation of IoT devices will feature cloud-based software solutions, device-based and edge computing, new approaches to power management and connectivity, and increased smarts via AI and machine learning.**

Connected devices have become an expectation: whether at home, in the office, or moving through the city, people rely on smart, interconnected devices and sensors making their lives easier, more productive, and more efficient.

Today, technical advances such as lower power chips, better connectivity, and advanced artificial intelligence (AI) and machine learning (ML) are unlocking new Internet of Things (IoT) use cases. Applications in healthcare, manufacturing, and transportation are taking off. A **McKinsey report projects** that, by 2030, IoT products and services will create between $5.5 trillion and $12.6 trillion in value.

IoT solutions, however, come with complexities. These range from developing sensing devices that offer secure cloud connectivity to generating insights for the end user. The semiconductor shortage and supply-chain disruptions caused by the coronavirus pandemic continue to impact suppliers and manufacturers. Different ecosystems, IP, technologies, and standards have made today's world of connected devices unfortunately fragmented and clunky. And simple, secure product development continues to be challenging.

To realize IoT's future promise, industry leaders must agree on standards to align device makers and manufacturers. IoT product, software, hardware, and chip makers – whether they are partners or competitors – will need to collaborate to create new features, products, and innovations and bring them to market faster.

Drivers of IoT growth

Industry, business, and consumer needs are steering IoT innovation: as technological advances open new use cases, certain key industries are driving the growth in connected devices. Factories and human health, for example, will account for 36% to 40% of the estimated unlocked value by 2030, **according to McKinsey**.

Innovations in the four enabling technologies of IoT – chips, connectivity, security, and artificial intelligence – are driving down costs and leading to better devices. Smaller, more efficient processors and wireless components will allow connected devices to further penetrate key markets, such as consumer appliances, cars and transportation, manufacturing and industry, and human health. Improved networks lead to more reliable connectivity, opening opportunities for previously infeasible applications.

As interconnected devices demonstrate their value, demand booms. Rob Conant, vice president of software ecosystems at Infineon, which provides semiconductor and software solutions for IoT companies, describes the spread of IoT applications across industry after industry, from fleet tracking in the 1980s, to industrial manufacturing and the smart grid in the 1990s and 2000s. He sees the spread continuing across diverse businesses: "Connectivity is extending into more and more applications: pool pumps are becoming connected, light bulbs are becoming connected, even furniture is becoming connected," he says. "So all of a sudden, companies that were not traditionally tech companies are becoming tech companies because of the value propositions they can deliver with the IoT. That's a huge transformation in those businesses."

Pandemic disruptions have highlighted the value of tracking materials throughout their supply chains. IoT devices help companies and manufacturers to optimize their manufacturing, based on the arrival of materials, and to update their production in near real time. "Being able to put sensors on goods that are being shipped, coupled with location tracking and mapping, lets you ensure the safety and the quality of the goods as well as optimize that supply chain journey for the lowest cost," says Dave Kranzler, general manager of IoT devices for Amazon Web Services.

Growing consumer demand for IoT devices is increasingly focused on home automation, and particularly on making the home more efficient and sustainable. Connected devices already deliver the ability to manage power consumption, temperature, and security systems, and smart homes and electric grids will continue to contribute to greater efficiency and manageability. Though lack of standards continues to hold consumers back, the introduction of Matter lays a foundation for wider adoption.

Consumers are also adopting technology that monitors their health and other aspects of their lifestyle. Smart watches and a variety of health-related devices – including heart monitors, glucose monitors, and sleep trackers – give people insight into their health and how they can improve it.

"The biggest traction we are seeing is around digital health – both human and machine," says Alessandro Grande, head of product at Edge Impulse, an integrated machine learning platform for smart edge products. "Enterprises are now able to create algorithms to analyze a system's state and performance and drive meaningful actions directly on the edge. With intelligent health monitoring, providers are able to increase the quality and length of human life, while enterprises adding smart monitoring to their machines are able to reduce costs and downtime and increase overall efficiency."

Better software and more intelligent management of devices through artificial intelligence and machine learning (AI/ML) will continue to improve device capabilities and flexibility, with applications in smart homes, green electrical grids, continuous health monitoring, and other advanced use cases.

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Rob Conant, vice president of software ecosystems, Infineon

Matter: Simple, secure, and sustainable interoperability

The proliferation of proprietary standards and service providers is a major hurdle for the adoption of connected devices. The current smart home landscape, for example, encompasses many closed ecosystems, including Apple's HomeKit, Amazon's Alexa, Google's Assistant, and Samsung's SmartThings.

To boost consumer confidence, those large companies are working with others in the industry to create Matter, a unified smart home standard. The common standard will ensure that devices from any manufacturer work together seamlessly, saving consumers setup and IT hassles.

Currently in its first version, Matter allows connections between smart locks, lighting, thermostats, security systems, sensors, and media devices, while simplifying development for manufacturers, according to the Connectivity Standards Alliance (CSA), the group behind the standard. The standard also accommodates over-the-network upgrades, reduces energy consumption, and improves device security. Devices that adhere to the standard and pass certification testing will gain a seal of approval.

Challenges for next-generation IoT

Though the market seems poised to expand, many companies have struggled to make IoT scenarios live up to their potential. While $1.6 billion in value was generated by 2020, that was the lower end of the market **McKinsey had forecast** five years earlier. More recently, **Forrester estimated** the chip shortage caused by the pandemic to have caused a 10% to 15% drop in growth for the IoT market.

As they work to make up ground, IoT product makers still have pressing technical challenges to address. These include integrating complex product components, exploring new connectivity solutions, managing power consumption, and wrangling the data these devices produce.

"IoT projects tend to take a long time to deploy and monetize, so even with the standards that are available now, this is not a 'just add water' technology," says Kranzler. "To build and deploy a complete solution, you need to integrate and test a broad range of technologies – devices, software platforms, applications, and analytics – and often these come from multiple vendors."

Wi-Fi 6E connects next-generation devices

Future IoT devices will use the improved Wi-Fi 6E standard for connectivity. The 6E standard extends Wi-Fi by utilizing more spectrum, creating more capacity for network traffic. This will be particularly useful in device-dense situations and when high bandwidth and instant responsiveness are required. According to Infineon, "the clean spectrum offered by Wi-Fi 6E improves user experience for teleconferencing, video and audio streaming, webcams and cameras used for live-feeds, due to Wi-Fi 6E's lower latency."

Network management tools and platforms for new 6E networks will ensure that improved experience by bringing their own smarts to the table—their AI and ML tools will be able to optimize network configuration to maximize performance.

On the connectivity front, improvements in bandwidth availability have made IoT useful in data-rich contexts, such as video doorbells and security cameras. But increases in the overall number of IoT devices and where they are deployed may cause new connectivity and latency issues. Current wireless technologies may be able to handle tens of thousands of devices, but as IoT devices become ever more prevalent, network congestion will become an issue.

Device reliability and power consumption also remain major issues. Batteries are the main power source for newer IoT devices, and many applications locate the devices in hard-to-access places or integrate them into other equipment. For that reason, some devices will require batteries with a lifespan on the order of 5 to 10 years.

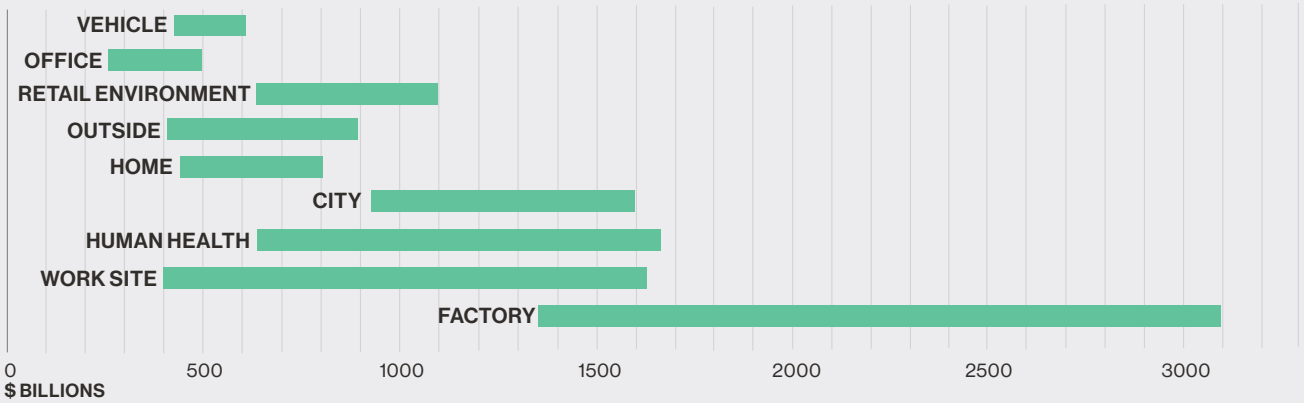
Meeting power consumption requirements may also mean designing devices with low-power processors, which limits their computing ability. This power consumption–processing power tradeoff will become a critical consideration, says Grande, especially as AI applications become more common. "Machine learning in the past required a lot of compute and was not able to run on the edge," says Grande. "Today's smart algorithms are running directly on IoT devices, producing actionable insights faster while reducing the need for always-on connectivity, resulting in massive power savings."

Once deployed, IoT devices then send a flood of data back to their owners. Businesses should expect that IoT device deployment will impose a need to manage that data, to store it securely, and to analyze it for business insights, says Kranzler. "The real challenge is how do you make use of all of that data?" he says. "Now that you can collect it and you can perform the basic use cases, how do you really get more value out of it than that? And that's where the challenge I think has now turned."

Emerging solutions for smarter IoT

New solutions will enable IoT manufacturers and device makers to address these issues and develop a smarter and more sustainable IoT future. Cloud-based solutions, device-based and edge computing, new approaches to power consumption and connectivity, and implementation of AI and machine learning will be key to the next generation of IoT devices.

Internet of Things 2030 potential economic value, by setting (billions of dollars)



Source: Compiled by MIT Technology Review Insights based on data from "IoT value set to accelerate through 2030: Where and how to capture it," McKinsey, 2021.

Cloud service providers can solve – or at least, abstract – many of the integration challenges currently facing IoT deployments. Cloud-based infrastructure can offer an organization prebuilt access to and management of its devices, with much of the needed software management expertise built right in. "The cloud provider provides all the investment in the hardware and the infrastructure necessary, keeps it running, keeps it up to date," says Kranzler. "It provides the investment in all of the basic software, what we call the undifferentiated heavy lift of being able to manage a large network of devices in a reliable and performant way. Cloud providers can also provide data collection or analytics platforms that help make sense of device data."

IoT applications that process data directly on edge devices will address bandwidth and latency. "The ability to do machine learning on the device itself enables new use cases," says Grande, "because it enables us to produce real-time insights without the need to transfer every byte of data to the cloud, allowing for overall faster and more reliable operations."

Similarly, Grande adds, "We are seeing more traction in pushing more processing to the edge." With distributed hubs closer to the devices, power consumption and bandwidth requirements can be reduced. Smart homes, smart cities, and commercial buildings will become hubs on the network that can each manage themselves and their collection of devices.

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Conant is enthusiastic about the ability of data and analytics to drive improvement in battery life and power consumption: "I think the biggest innovations around power consumption are coming out of real-world data analytics. Through testing at scale in the field, we were able to improve our embedded Wi-Fi algorithms to triple battery life for 20% of customers. That's massive."

Different types of low-power networks will address both connectivity and power-consumption challenges. Often used for applications that require either low bandwidth or short-range networking, they use Wi-Fi-alternative protocols such as Bluetooth, Thread, LoRaWAN, IEEE 802.11ah, or Zigbee. Amazon Sidewalk, a shared-network technology linking existing Amazon IoT devices, was a notable 2021 launch in this area.

The addition of AI and ML abilities to IoT deployments will be a key shift. With more intelligence on board, IoT devices can manage their own connectivity or even repair themselves. Sensor data captured by the device can be reduced to only the important and useful information, increasing efficiency and performance. With better machine-learning techniques, devices can be made more resilient even when operating in places of reduced communications or lower power, says Conant.

The upshot of these solutions will be an IoT future that is more reliable, more intelligent, and more sustainable. Fully capitalizing on IoT's potential, however, will require tackling a host of technical challenges, forming cross-industry standards and partnerships, and imagining new use cases for devices with next-generation smarts.

The market is eager for IoT advances, and applications with clear business cases behind them are likely to thrive. Says Kranzler, "The easier we make it for people to build, deploy, and monetize multi-vendor solutions in a way that drives down costs, the more innovation it fuels, and the more you get that flywheel spinning."

Connectivity drives sustainability

Connected devices can be major contributors to sustainability. Because economic value incentivizes adoption, IoT solutions that reduce costs by saving energy or increasing efficiency can expect rapid uptake.

Smart buildings and appliances use the right amount of energy at the right time, with sensors switching on heating and cooling, refrigerators, and lighting only as needed. Added smarts increase the opportunities for efficiency. Devices that monitor their own output can alert users to the need for maintenance before their performance declines. Responsive devices can toggle to low-power modes when not in use. And advanced monitoring, analytics, and machine learning algorithms can help devices learn to be smarter in their energy consumption.

The magnitude of the impacts will be transformative. Dave Kranzler at Amazon Web Services cites an industry study showing that deploying smart metering and in-home displays in Europe led to a 9% reduction in energy consumption. "Nine percent may not sound like a huge number," he emphasizes, "but 9% of a huge number is still a huge number."

A 2021 whitepaper by Transforma Insights and 6G World projects that IoT applications will save 1.6 petawatt-hours of electricity, 3.5 petawatt-hours of hydrocarbon fuel, 230 billion cubic meters of water, and 1 gigaton of CO_2 emissions by 2030. Business and industry will drive the decline, with smart electricity generation, vehicle fleet management, and power grid and metering leading the way.

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