WHITE PAPER

IoT TO AIoT - ACCELERATING DIGITAL TRANSFORMATION

Abstract

The convergence of Artificial Intelligence (AI) and the Internet of Things (IoT) can unleash innovation and transform digital adoption across industries. AI can analyze massive volumes of data, identify patterns, and extract meaningful insights, while IoT solutions generate real-time data through its interconnected sensor network, devices, and platforms. So AIoT is bringing together these two technologies to unlock value for enterprises. The applications of AIoT span industries such as manufacturing, healthcare, transportation, and logistics, and they significantly impact product development lifecycles. However, implementation challenges need to be addressed as the technology matures. With the advent of Generative AI, there is immense scope for innovation in the future to imagine newer use cases that deliver unprecedented value.

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Introduction

The International Data Corporation predicts 55.7 billion connected devices will generate 80 zettabytes of data by 2025 [1]. There is a massive opportunity to extract value from the data, so the convergence of AI and IoT is obvious. IoT adoption across the consumer and enterprise paradigm is accentuated by pervasive connectivity, hardware commoditization and differentiation through software. AI imitates the human intelligence process by computing systems. It has become apparent that AI needs data to learn and grow, which is where IoT helps by collecting and transmitting data. Together, the technologies have a disruptive effect on industries, businesses and consumers.

In the functional view of AI and IoT, sensors create or sense the data, which is then communicated over the network to the platform, aggregating the data to derive meaningful insights, augmenting intelligence, and finally pushing towards a decision regarding response to the data. AI helps interpret patterns to produce new capabilities that have not been considered. Examples include intelligent device onboarding, automated traffic management, devices updating their machine learning models, synthetic data generation, etc. Clearly, an intersection will deliver far greater value than the individual technologies independently.

In this paper, we trace the history and evolution of AI-driven smart connected products and how they deliver value to their customers; subsequently, there are two views of use cases – an industry perspective and a product development lifecycle view. A few real-life examples across industries will help illustrate the impact of AIoT on digital transformation. There are always associated challenges when embracing emerging technologies, which are discussed and potential ways to address them. The art of the possible is explained with a sneak peek into the future, and the paper concludes with how AIoT can help accelerate transformation.

Evolution of AI-driven smart connected products

The evolution of AI-driven connected products has gone through multiple phases, as shown in Figure 1. Physical components make up a product's mechanical and electrical parts. For instance, the engine, tires, and body of a car make up the physical components of a car. As the next stage of evolution, smart components were introduced in the product, such as sensors, microprocessors, data storage, software, embedded operating system, and enhanced user interface. In the car example, the Electronic Control Unit (ECU), Antilock Braking System (ABS), Advanced Driver Assistance Systems (ADAS) and touchscreen displays make it a smart car [2]. As connectivity became ubiquitous, offboard processing (Telematics) offloaded compute-heavy processing to the cloud. A combination of onboard and offboard led to new capabilities and experience. Most importantly, connectivity enabled feedback to be added to the product development lifecycle. The functionality of smart connected products can be broadly classified below, where each functionality incrementally adds to the previous feature.

A. **Monitoring** functionality enables constant monitoring the product's condition, performance, and external conditions and, importantly, allows alerts and notifications when preset thresholds are crossed.

B. **Controlling** product operations uses the product software based on feedback and usage. It allows personalized user experience based on preferences.

C. **Optimizing** product performance based on the product condition, performing diagnostics and preventing failure or downtime through preemptive mechanisms.

D. **Autonomy** is when the product can self-diagnose, repair, and coordinate with other products in the ecosystem to deliver integrated solutions.

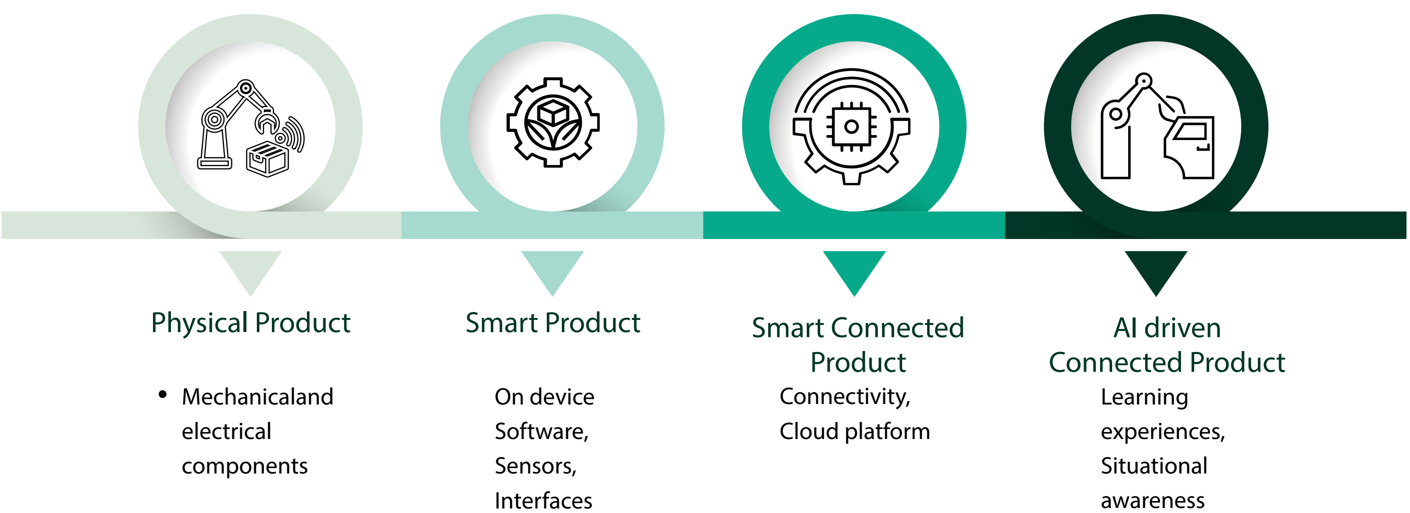


Figure 1 – AI-Driven Connected Products Evolution

Smart, connected products are redefining strategic choices for companies on how value is created and captured. They are reshaping industry boundaries, expanding industries and creating newer avenues for companies to deliver value to customers. For example, in agriculture, smart connected farm equipment is part of a more extensive system of systems, including weather, irrigation and seed optimization, to provide an integrated farm management system [2].

Smart Connected product is the foundation for data, which acts as a fuel for driving AI. Adding AI takes this evolution to the next level by integrating learning and situational awareness into smart connected products. The ability to unlock and amplify value is exponential since the paradigm is shifting from rule-based to learning. The interfaces adapt to user behavior, environmental behavior, historical data, and actions are highly contextualized. Examples include dynamic routing that is not rule-based, dynamic assembling of devices, automated metadata tagging, and anomaly detection, which enhance the capabilities of smart connected products. Adding the learning dimension enables newer ways to use products that were not conceived during the design stages. The paper details the art of possible use cases from an industry and product lifecycle perspective in the next section.

AIoT enabled Industry and Product Lifecycle Use Cases

Use cases are the best way to understand and appreciate the impact of emerging technologies by providing a pragmatic application of the technology in real life. This paper analyzes the use cases through two lenses: Industry and Product Development Lifecycle. We have considered transportation, manufacturing, and healthcare examples, which can also be extended to other sectors.

AIoT impacts the industry in three key aspects: the topline, bottom line and product experience. Unlike IoT, which only affects the business, AI also transforms the product development lifecycle. The application of AI is accelerating time to market, increasing productivity and enhancing product quality. In this evolution towards connected products and AIoT, the increased value from the mechanical component of any product remains flat. In contrast, the value of electronics and software in any connected product is higher. AI is driving significant value from electronics and software compared to the other components.

Industry Use Cases

Industry use cases from three sectors have been illustrated in Figure 2.

A logistics company in the transportation industry can use AIoT for fleet management and demand forecasting through real-time location and vehicle data collection. A fleet management system can optimize routes, effectively hand over in multi-modal transportation, predict ETA based on several parameters, and perform preemptive maintenance of vehicles. Historical data analysis can be used to forecast demand for trucks and equipment, which can enhance efficiency.

The manufacturing industry has adopted IoT over the last few years through Industry 4.0 initiatives and is now experiencing the impact amplified through AI algorithms. The maturity increases from understanding what is happening to why something happened, what will happen next and what needs to be done when something happens. Real-time data from the shop floor drive this continuum and can help predict equipment failures by analyzing machine/sensor data and historical maintenance records. This approach enables proactive scheduling of maintenance activities, minimizing unplanned downtime, reducing maintenance costs, and optimizing production output. The factory of the future will be autonomous, self-healing, and fully automated and is likely to be a competitive strength.

Lastly, let us look at the application of AIoT in the Healthcare industry. The use cases vary from diagnostics, detecting fraud in billing, and personalized treatment to hospital operations. They include using AIoT technology to enable doctors to remotely monitor patients and alert hospital staff and doctors if vital parameters are below a certain threshold. In addition, AI algorithms can analyze neurological imaging and discern minute variations to predict conditions such as stroke, brain hemorrhages and tumors. There is a clear impact on outcomes through preventive and predictive diagnostics that are personalized.

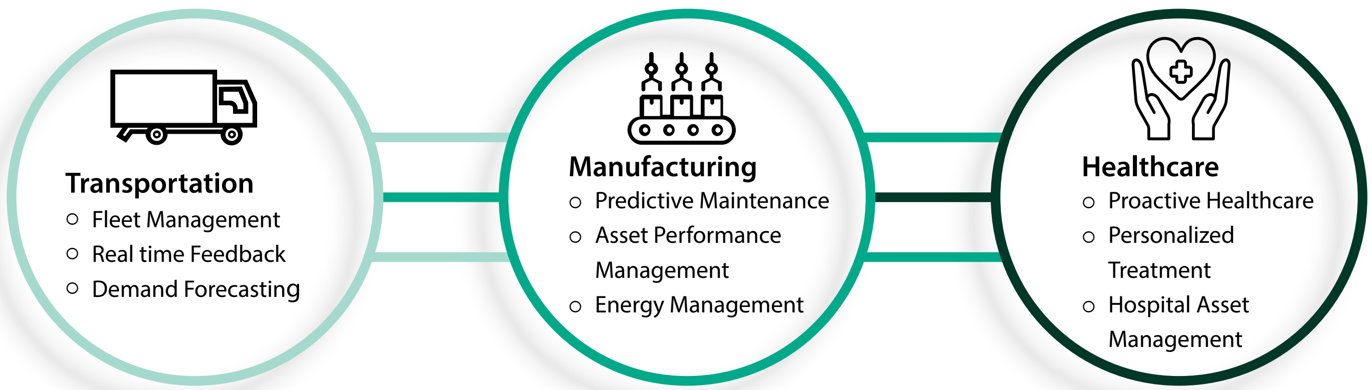


Figure 2 – AIoT Industry Use Cases

Product Lifecycle Use Cases

The product lifecycle use cases are illustrated in Figure 3 according to the lifecycle stage. A PwC study says that 14% of enterprises using AI and ML for new product development earn more than 30% of their revenues from fully digital products or services [3]. In fact, the application of Generative AI is high in the product development lifecycle - for instance, analyzing market trends and identifying white spaces by processing high volumes of data. In the product design phase, Gen AI/Generative Design can offer multiple design options rapidly based on user requirements – imagine asking the system to suggest alternatives based on material, supplier, cost and customer feedback. The Generative Design is made robust by data feedback from the connected product on the field. This data helps the engineering team improve the design, change the manufacturing process to make it more efficient and improve quality and service levels. In contrast, the manual alternative would be time-consuming, cumbersome and error-prone.

There is a significant impact in the build phase of a product, especially so in the software world. Early adopters of tools such as Copilot report a 20% developer productivity improvement while reducing errors [4]. Similarly, there is a challenge in creating test scenarios, such as generating test data for a turbine machine shutting down or an autonomous vehicle crashing. Synthetic test data is about generating the test values without actual hardware/system for such scenarios and observing the system's reaction. This helps in faster time to market and the right first time product.

During deployment, automated deployment and A/B testing are pretty common. There are unique scenarios where AI can help find the optimal configuration, such as how Siemens uses complex AI algorithms to determine the optimal configuration for its interlocking railway equipment product lines and systems. Honeywell uses AI to reduce energy costs by tracking and analyzing price elasticity and sensitivity [5]. It also integrates AI and ML algorithms in its new product development process across procurement, strategic sourcing and cost management across stages.

Finally, during ops and maintenance, there are multiple AI applications. Predictive maintenance based on historical data, anomaly detection and recommending the closest fit resolution based on the issue are all tasks perfect for algorithms, resulting in lowered downtime and higher utilization. AI systems can continuously analyze historical and real-time equipment, inventory, and purchasing data to help maintenance teams maintain optimal and right-sized inventory. Furthermore, virtual assistants are omnipresent in customer support and can perform complex tasks.

1 Design

- Analyze market trends
- Explore design options
- Enhance experience

2 Build/ Manufacture

- Automate code generation
- Synthetic data for testing
- Create documents/ playbooks

3 Deploy

- Improve demand forecasting
- Optimized product configurations
- Automate deployment

4 Operations / Maintenance

- Leverage virtual assistants
- Enable predictive maintenance
- Optimize inventory

Impact

The convergence of AI and IoT profoundly impacts the industry and product development lifecycle. This section describes the impact in detail, as illustrated in Figure 4.

a. Operational efficiency—Efficiency is about closing the feedback loop when real-time data is fed back to a system to take decisive action. Examples include rerouting when there is traffic in a fleet management scenario or predictive maintenance to increase equipment uptime.

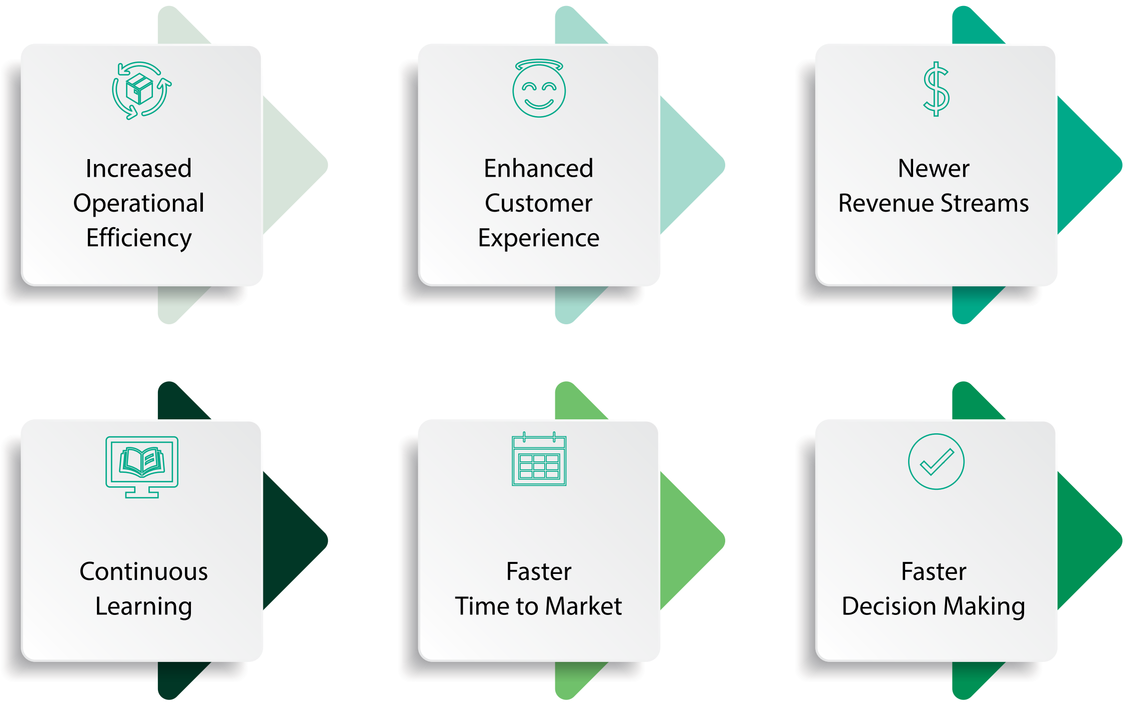
b. Enhanced customer experience— predicting behavior and presenting options to the customer. For example, thermostats that learn behavior based on your settings, outside weather, and other factors can automatically adjust or suggest optimal temperatures.

c. Increased revenue—The services-driven economy of connected products enhances revenue-generating potential. From a one-time sale, the paradigm has now shifted to recurring revenue. Innovative opportunities exist to create and deliver value through a connected ecosystem and increase customer stickiness.

d. Amplified autonomy - The ability for devices to work in a decentralized fashion and continuously update based on analyzing and aggregating local data increases autonomy and facilitates continuous learning. Edge devices communicate with each other, update the local models, and decide when to update the back-end platform.

e. Time to market—Gen AI profoundly impacts the product development life cycle. Auto code generation, test case suggestions, and synthetic data generation have all compressed the time to market. When coupled with automated deployment, getting it right the first time and every time starts becoming a reality.

f. Decision-making—With real-time data, intelligent insights from data analysis and recommendations improve decision-making. Decision makers get responses to "what-if" scenarios and are presented with options previously not considered, leading to faster decision-making and, in some cases, ratifying system decisions.



Challenges in AIoT Implementation

As with any emerging technology, implementation challenges exist. Technology maturity vs. challenges is a healthy push-pull mechanism that eventually pushes the technology forward. Here are some of the challenges in AIoT implementation.

Security: Because of the interconnected nature of IoT, security issues quickly cascade across the network. The surface area for security attacks is also high, i.e., the device, communication networks, gateways, and finally, the cloud platform—each component in the entire IoT stack is vulnerable to attack. Addressing security concerns is a continuous activity. Defense in-depth mechanisms, updatable security protocols, secure application development practices and zero-trust security are some techniques to protect the devices and network.

Data Management: Given the massive volume of data being generated, there are challenges around data transmission, processing and storage. Vulnerabilities are exposed without adequate data governance and rules to manage this data efficiently. Secondly, data is the bedrock of AI, so data integrity is crucial to insights and decision-making. Plus, data management is critical for explainability and addressing bias issues. Data Governance is critical, especially regarding Data Sovereignty and Data Compliance.

Interoperability: IoT integrates disparate technology and systems, and this diversity across manufacturers and supported protocols has always led to interoperability issues. In addition, there are challenges in sharing data between platforms. While standardization has been a way to address the interoperability issues, the first mover advantage is something that device makers will want to protect. Standardizing the message protocols and using open interfaces to communicate between components are ways to address interoperability issues.

Compliance: Given the disparate and interconnected ecosystem, policies and regulations must govern the landscape. In addition, there are global differences in regulation definitions and compliance requirements. All stakeholders must actively formulate these guidelines, while governing bodies and regulatory agencies are responsible for maintenance and upkeep.

Privacy: The interconnected nature of AIoT systems introduces privacy risks and must be proactively addressed throughout the product development lifecycle. The sensitive nature of data and the fact that it transcends multiple networks necessitate robust privacy protection technologies. Anonymization, homomorphic encryption, and differential privacy are some techniques that can be used to balance privacy requirements and leverage AI.

Ethics: While AIoT's transformative capabilities are massive, ethical and societal considerations must be examined. Addressing bias in AIoT systems is crucial for equitable and fair decision-making. Similarly, there must be a heavy emphasis on transparency and explainability—both vital for building trust. Organizations must embrace accountability and emphasize responsible AIoT design and development. Ethical considerations must be proactively addressed in the initial stages of development through responsible design techniques, compliance with regulatory requirements and adequate measures to increase public awareness.

A peek into the future

While we see significant edge computing already in autonomous vehicles and other devices, the actual impact is yet to be seen due to multiple challenges, such as interoperability and lack of standardization. However, there is enough room for edge and ambient computing to deliver personalized n=1 experiences. Imagine a conference where you have pre-registered. At the entrance, a personalized greeting with your schedule is clearly shown. Furthermore, there are helpful directions to lead you to the correct conference room through indoor positioning. Based on your preferences, suggestions are made for sessions, networking, and more. While this can happen in a public place, imagine the possibilities at your home.

We have discussed many examples of discriminative AI in the paper; however, Gen AI holds much potential yet to be explored, such as some examples of Copilot and synthetic test data where Gen AI has a lot of promise. Business use case examples exist. For instance, Siemens uses Gen AI to design and optimize parts for gas turbines. The algorithm can generate thousands of design options, which would be impossible manually. There are two significant advantages of this process. Firstly, it is the ability to explore multiple design options and decide on the best fit; secondly, it has an incredible impact on productivity and time to market. Another example is how BMW uses Gen AI and IoT to simulate multiple configurations for its production assembly line to decide on the most efficient and cost-effective manufacturing process. Innovative use cases will emerge as these technologies mature, growing significantly beyond the two we discussed.

Lastly, the role of the network and ecosystem amplifies the value across the landscape. There are opportunities for a connected ecosystem with near real-time data shared across these ecosystems – for example, in smart cities, with multiple ecosystems interacting to create, amplify and deliver value to the consumer. The power of AI can create interactions dynamically across these ecosystems to provide contextualized and personalized experiences to the consumer.

Conclusion

The convergence of AI and IoT will unlock tremendous value for enterprises and consumers. The cost of sensors, compute and connectivity led to the large scale deployment of IoT across the industry sector. Similarly, the cost of GPUs and special purpose CPUs used in AI will commoditize AI for large scale adoption and cost-effective implementation of AI complementing IoT. The paper outlined some industry and product development use cases and the business impact these two technologies create. IoT feeds the data required for AI algorithms to extract insights and make connections that would not have been possible manually. There is a paradigm shift to creating newer revenue streams, enhancing the usage and service experience while delivering operational efficiencies. In summary, it impacts all three pillars of running a business. As with any emerging technology implementation, some challenges continue to push the technology forward.

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