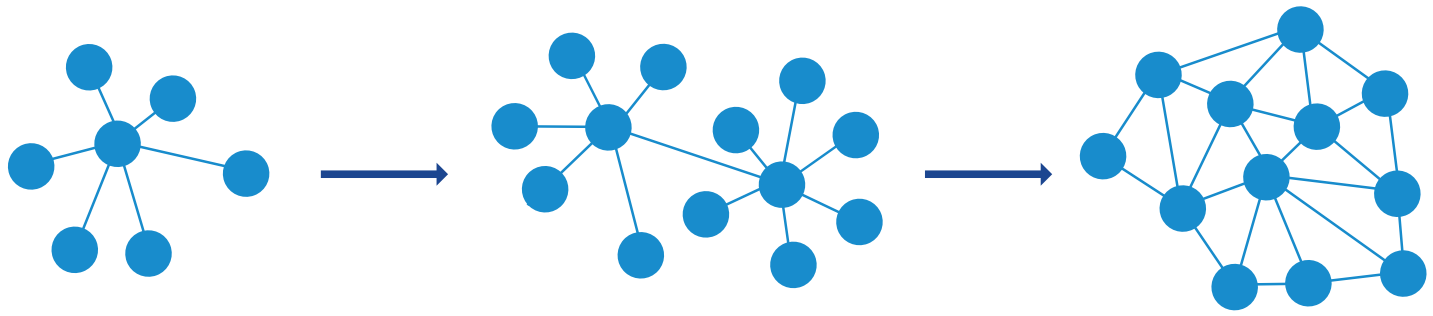
THE EDGE. REDEFINED.

The Future of the 'Internet of Things' is Distributed Intelligence

The Internet was born out of a centralized structure, later migrating to a distributed 'client-server' model. Twenty-five years later, with the advent of mobile and cloud, computing architectures became centralized again. Now, the Internet of Things (IoT) is again changing the paradigm and creating a digital world where all "things" connect to the network, providing anyone with "anywhere, anytime" access to information.



Centralized Intelligence | Decentralized Intelligence | Distributed Intelligence

WHY NOW?

As sensor technologies and networked applications pervade every industry, the gravity or weight of *so much data generated by so many diverse IoT consumer and enterprise devices*, renders centralized computing topologies inadequate for the IoT to mature. The pull by data generated locally at the edge therefore justifies expanding the cloud compute model to the edge as well. For the IoT to reach scale and mature enough for customers to adopt it rapidly, performance, and therefore computational agility or intelligence, must move closer to the edge of the network where the action takes place. Instead of relying purely on cloud infrastructure to process data, local compute 'at the edge' enables greater speed, flexibility, security, privacy, economy and scale.

With the cost of bandwidth not falling as fast as the costs of compute and storage, the ability to aggregate and filter data *locally on the device* becomes meaningful and serves an economic justification: edge compute decreases reliance on bandwidth, in short, reducing the cost of bandwidth for specific use cases. While there are explicit use cases where cloud is better, for high tech—high touch applications that are latency sensitive and bandwidth intensive, local is preferable. And, the growing number of connections between things and people will push IoT use cases to even more dynamic, contextual and real-time interactions, hence accelerating intelligence at the edge.

AGILITY AT THE EDGE, LEARNING IN THE CLOUD

Perhaps the most disruptive impact of offloading compute from the cloud to the edge is its role in *balancing computational intelligence between the endpoints and the cloud*. Intelligence at the edge means *agility*: real-time response and decision-making in dynamic environments. Intelligence in the cloud means *learning*: multi-modal data aggregation, analysis, modeling, predicting, and recommending more strategic alternatives. Put simply, it's enabling intelligence in every part of the body or in every endpoint at *the edge*, while taking greater advantage of intelligence of the brain or *the cloud*.

Enterprises now have the capabilities to define, filter, aggregate and process data locally, while being enabled to upload data back to the cloud for analytics, innovation, and more sustainable storage and data management.

In industrial sectors like agriculture, aerospace, mining, healthcare, or energy, reliable connectivity can be limited. Devices and equipment generate massive amounts of data chatter, placing unnecessary constraints on networks and battery life. Failure can cost significant revenues, time, even lives. Edge compute provides local compute and storage to improve latency when critical real-time decision-making is required.

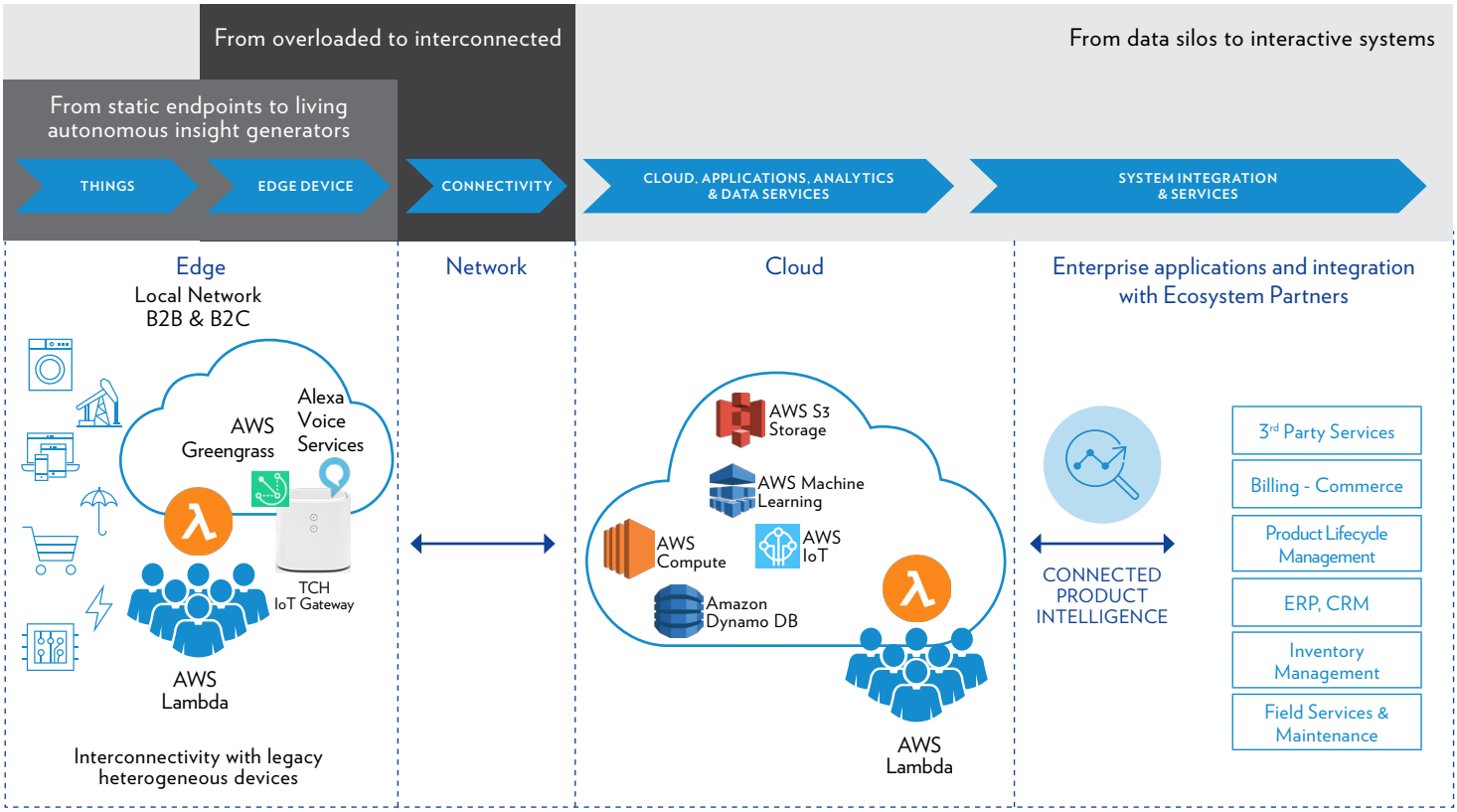
In consumer markets, current IoT implementations have fallen short of expectations—unmet needs for interoperability between devices, inadequate monetization for providers, poor user experiences (UX) for end-users. Privacy concerns stifle consumer adoption and regulatory compliance requirements in certain geographies mean some data are simply better left local to the device. Edge compute enables sensitive data to be analyzed and acted on without moving it to the cloud, while reducing bandwidth needs through local processing capabilities and improving latency for data intense interactions.

Pushing Intelligence to the Edge Impacts the Entire Value Chain

While the justifications for shifting greater processing to the edge are clear, the implications for distributed computing has a ripple effect across the **entire value chain** as well as on the underlying business models.

When IoT devices themselves are equipped with greater compute power and filtering capabilities, new opportunities for use case optimization and innovation sprout across every part of device, product, service and customer lifecycles. While more and more workloads are born in the cloud or move to the cloud, there is now also the capability to process data and specific workloads at the edge, meaning a shift from value creation in the cloud only, towards creation of value at the edge *and* in the cloud, and over time *in every point in the network*. Edge compute capabilities also inherently bring the open API world of the cloud paradigm to the edge, allowing developer communities to become active innovative stakeholders in the value creation process.

VALUE CREATION AT ENDPOINTS IMPROVES THE WHOLE



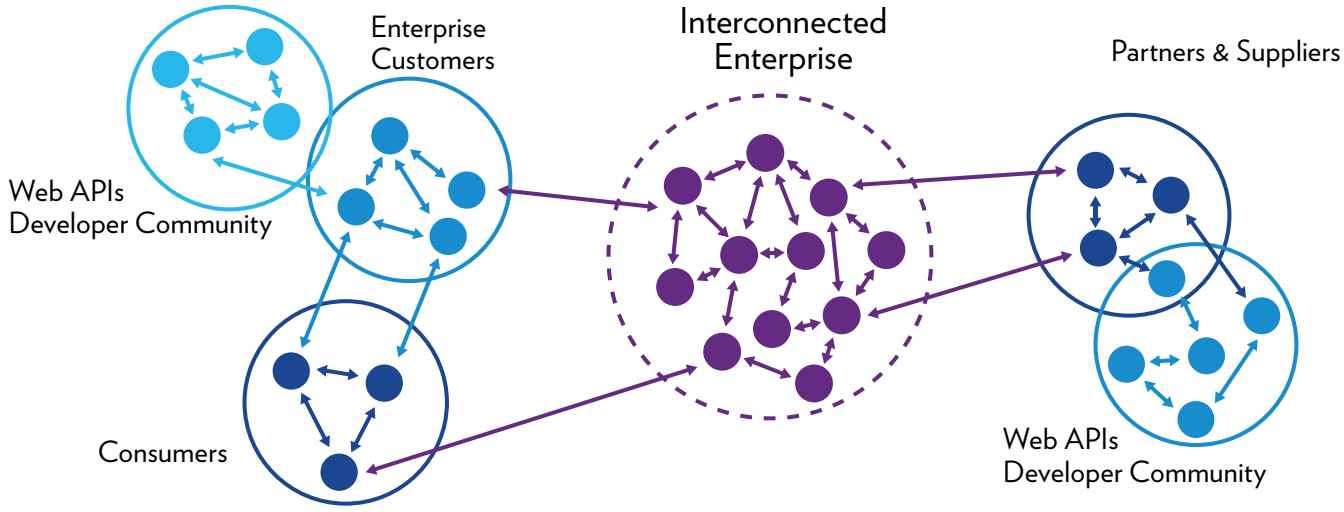
ELEMENT OF IoT	IMPACT	BENEFITS
Edge devices	• Edge-processing enabled devices and IoT Gateways support dynamic services and interoperability through a Web API approach. • Shift from product-level connectivity to using products as a catalyst for distributed ecosystem-level intelligence. Endpoints act as local data information brokers, and become fully interoperable platforms for receiving and executing updates. This shifts the role of product design. Instead of a static, quickly obsolete blueprint, updated once per manufacturing cycle, endpoints act like 'living' assets. • Increased computing power now enables on-device capabilities like out-of-the-box voice-interaction. This makes the onboarding for end-users of IoT devices easier.	• Interoperability between devices through a Web API based approach unlocks value creation between stakeholders in the ecosystem. • Intelligence at the edge lowers cost of data-intense, high latency use cases. • The product's value and customer loyalty increase over time through greater personalization, new and better services, and more compelling experiences. • Open development ecosystems help augment businesses' abilities to innovate at the edge. • Plug and Play and ease of use improve user adoption.
Connectivity	• Edge-level processing helps relieve bandwidth constraints for existing use cases, and simultaneously opens entry of high performance applications at the edge because of better processing capabilities.	• Bandwidth optimization for data intense use cases through local data processing capabilities. • Edge capabilities unblock the entry of high tech–high touch use cases previously not viable economically due to high bandwidth cost. • Connectivity providers benefit from the simultaneous increase in demand for bandwidth to accommodate advanced machine learning and increased analytics in the cloud, while at the same time offering the capabilities to relieve bandwidth through distributed intelligence at the edge. • IoT Gateways create new interactions and use cases through Open APIs.
End-to-end data processing capabilities and integration	• IoT data from the edge can merge with other database analytics systems for 'end-to-end' analytics, resulting in processes becoming smarter across other functions such as customer support, field service, sales, marketing, suppliers, partners, etc.	• A more 'holistic view' that paves the way for new interconnected services. • Processes become smarter across other functions such as customer support, field service, sales, etc. • Data coming from endpoints accelerate next generation designs and optimize the supply chain. • Greater intelligence at the edge means less manual support, and enables predictive, even preemptive maintenance.

IOT MONETIZATION: WHERE IS THE MONEY?

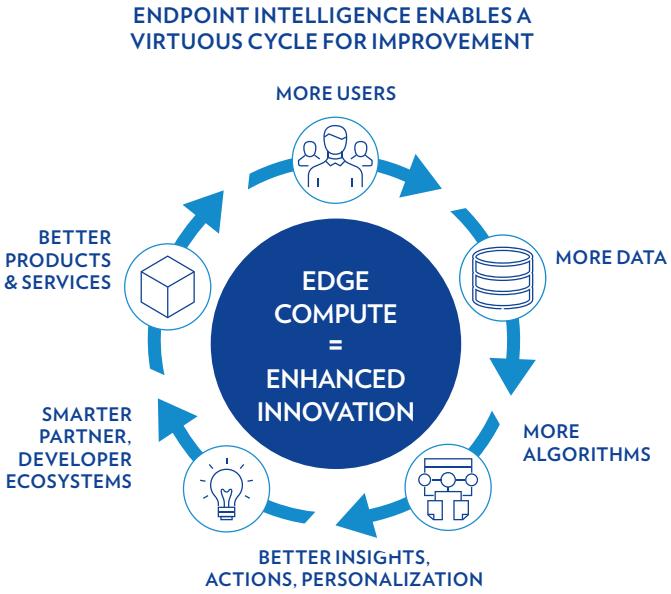
Smart, connected products offer countless opportunities for new functionality, greater reliability and higher product utilization. New capabilities can augment traditional product boundaries and open paths to new forms of digital innovation. But for this to happen, IoT needs to move beyond its early adopter phase and reach a level of "Plug and Play" maturity that appeals to less tech savvy enterprise users and consumers.

This implies an emphasis back to the essence of IoT: connecting *every thing* or understanding the implications of interdependencies due to being connected with other companies, consumers, developer communities, etc., through technical and business ties. Many companies did transform their products into IoT-enabled services strategies, but to sustain these service-based business models and stay competitive, they also need to be ecosystem-enabled. For example, when the software that informs a product is part of a broader open development ecosystem, an Open API approach allows for a service-based business model to evolve, instead of remaining static. As such, IoT pushes companies to design services that consider the *ecosystem nature of IoT* rather than emphasize the individual company objectives.

ECOSYSTEM-ENABLED BUSINESS MODELS



The transformation of IoT architectures from centralized towards distributed network structures with more intelligence closer to the edge, increases the complexity for businesses to design interconnected business models. Different parts of the network will now emphasize different types of activities in the ecosystem that create value independently, yet in an interconnected way. While existing business model frameworks are adequate to examine the challenges faced by a single company, they are less suited to evaluate the interdependencies between companies that are intertwined with each other. Ecosystem-enabled business models focus on mapping interdependencies between multiple applications that communicate with each other as a network, and thus beyond the boundaries of a single company. It models the efficiencies across the entire value chain.



To exemplify: more data, processed more intelligently, accelerates the extraction of insights, which leads to smarter and more frequent improvements and innovations to products and customer experiences. More customers lead to more data, and so on. Through APIs, applications and analytics, products and services grow smarter and more aware, contributing to and learning from systems beyond themselves, with each new interaction and each new connected device. This *virtuous cycle* empowers companies to deliver products and experiences that 'appreciate' in value due to being part of an ecosystem. In a connected IoT world, new features and functionality can be pushed to a customer base on a regular basis. Customer behavior can be tracked and products can be connected to other products, leading to new analytics and new services for more effective forecasting, process optimization, and customer service experiences.

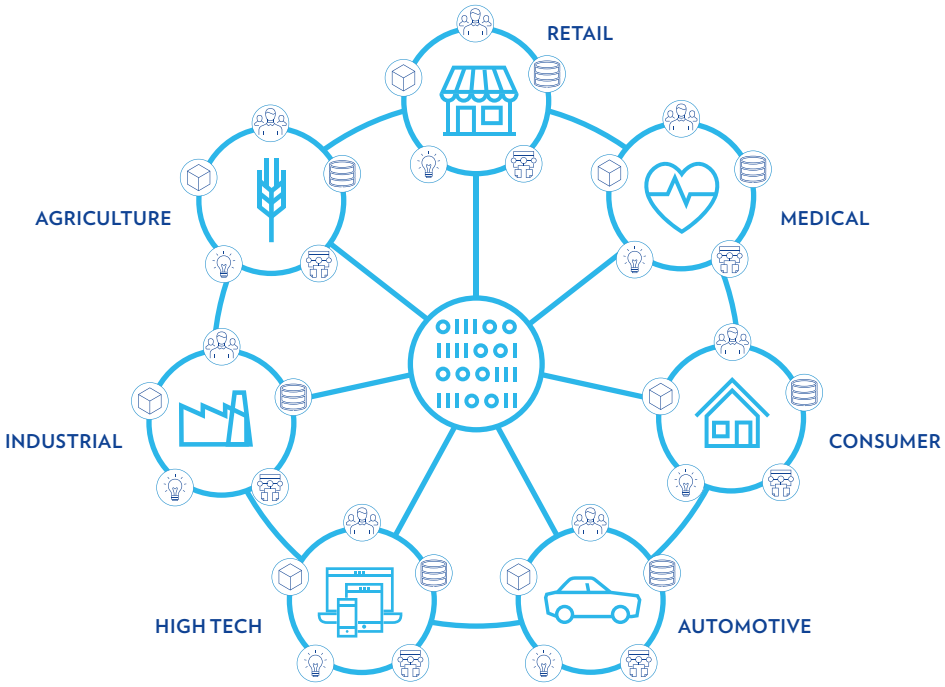
Other emerging technology advancements like machine learning and Artificial Intelligence (AI) taking place at every level of the technology stack—from neural networks on a chip, to embedded learning in mobile devices, to significant breakthroughs for AI in the cloud— will only augment the potential for greater device autonomy and self-organizing network capabilities at every level. The system develops through co-evolution, with high levels of self-organization in the endpoints and adaptation to the environment through the cloud interactions.

REALIZING NETWORK EFFECTS

Network effects kick in when goods or services become more valuable as more people, things or ecosystems use them. They determine the overall success of IoT services and ecosystems and hence also impact the monetization. Put simply, a rising tide—of endpoint intelligence—lifts all boats; that is, ubiquitous connectivity and ecosystem-level learning.

NETWORK EFFECT ON VALUE CREATION ACROSS ECOSYSTEMS

Distributed Intelligence has Network Effect on Value Creation Across Sectors



Yet, the myriad of connected objects and devices, from toothbrushes and sportswear to refrigerators and cars, lacks commonly accepted standards for interconnectivity. Whether there will ever be standardization of the interfaces to connect to the IoT remains unclear. To that effect, the IoT today results in vertically integrated silos that solve point specific solutions, be it for a specific industry or centered around specific IoT platforms. This fragmented approach furthermore prevents much needed adoption, and through lock-in ***breaks network effects, hence affecting monetization***. Broad interoperability is needed to unblock value and achieve the next level of the IoT where diverse resources are managed together as single systems. De facto standards from the cloud leveraging Open APIs, however, provide the means to build horizontal capabilities in a *different way,* enabling interactions between things, devices and ecosystem stakeholders.

Stakeholders of the ecosystem can be, for example, an IoT Gateway supplier, a supplier of cloud infrastructure, a supplier of hosted solutions or smart services, a network service provider, a managed service integrator, and an open source developer community. Where the IoT Gateway can provide protocol translation through Web APIs using developer communities, this now also provides enormous value for the other stakeholders in the ecosystem. Instead of focusing on one key stakeholder, the emphasis is placed on the generation and capturing of value for the entire ecosystem. In this example, the highest value would traditionally be achieved at the moment where the data is transformed into action in the value chain. This however neglects the value of other stakeholders that enables the action to happen in the first place.

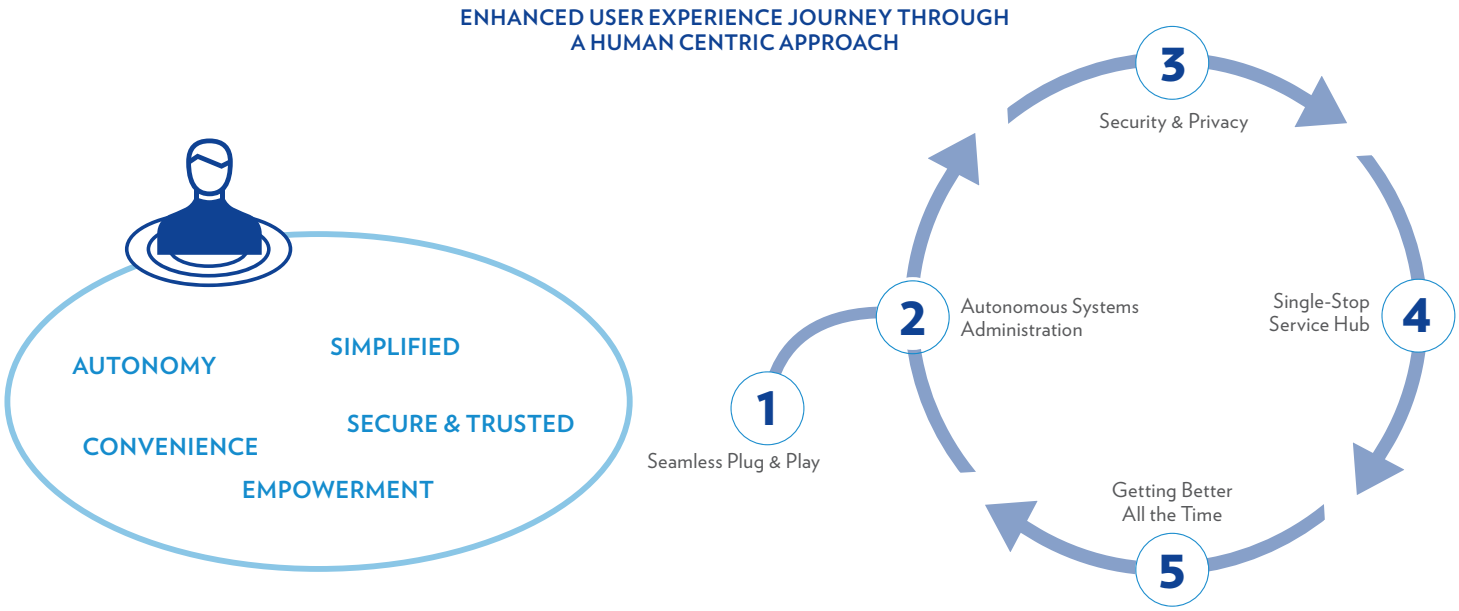
It also addresses the much-asked question: "Who owns the data?" The real question is how to build services with respect for user's privacy or sensitivity of data while optimizing specific and secure data flows through ecosystems that improve and optimize end-user experiences. When ecosystem stakeholders share and enrich data across their ecosystems, the IoT will enable massive digital business transformation of operational processes that results in improved customer experience and reduced operational costs. Without it, network effects will remain limited to affect monetization.

The Edge Unleashes the Potential for New Services and Experiences

While the move to the edge was triggered by the practical realities of the physical world and the tactical needs for real-time data processing, the broader implication of this shift is its role as a force multiplier of new services and experiences. New use cases abound for both end-users and enterprise adopters.

BUSINESS-TO-CONSUMER: ENHANCED END-TO-END IOT CONSUMER EXPERIENCES

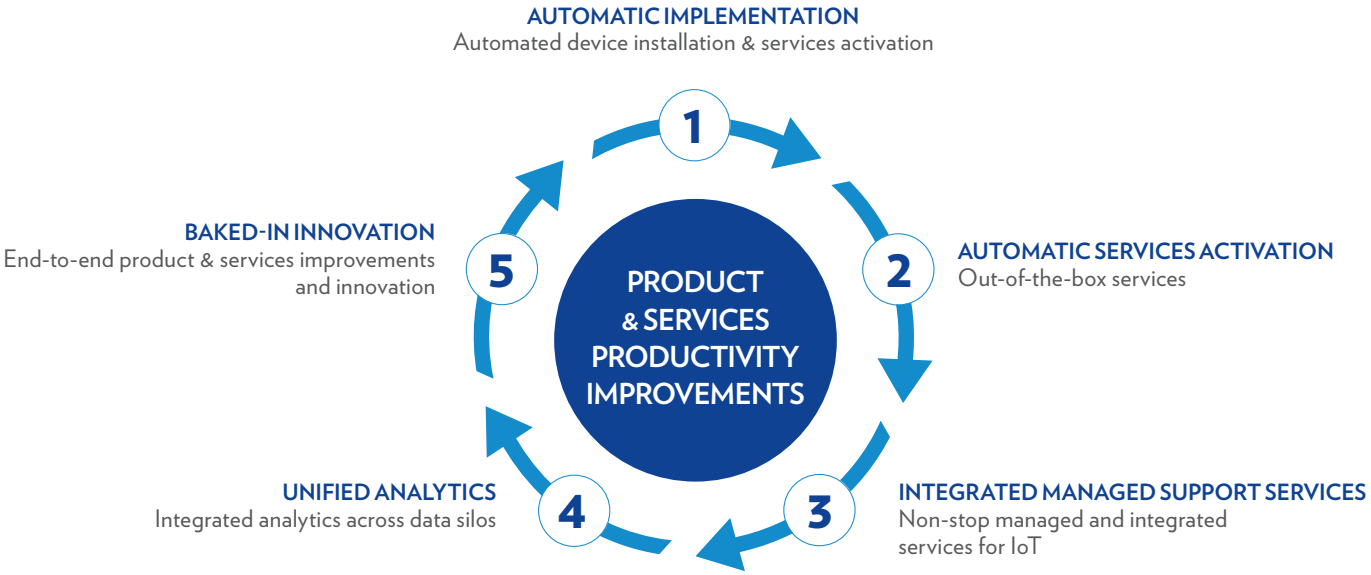
From an end-user perspective, an affordable in-home device equipped with seamless plug-and-play, voice interaction, and open standards for improvement will foster adoption—adoption by non-technical, diverse backgrounds which comprise the majority of the consumer IoT market.



1 SEAMLESS PLUG & PLAY	2 AUTONOMOUS SYSTEMS ADMINISTRATION	3 SECURITY & PRIVACY	4 SINGLE-STOP SERVICE HUB	5 GETTING BETTER ALL THE TIME
Activating new devices and connected services is easy. When gateways are voice-supported and equipped with automated detection of nearby devices, users' onboarding experience is a matter of 'powering-on' and speaking. Behind the scenes, the edge-enabled gateway automates provisioning of devices, finding Wi-Fi, identifying and executing updates, activating new services.	Instead of forcing users to become IT systems admins, edge compute-enabled devices handle the cumbersome but critical burdens of performance and network monitoring, anomaly detection, identity authentication, permissioning, and encryption, even facilitating better connectivity and quality of service by automating channel changes, roaming decisions, and Wi-Fi optimization.	Technology that allows users to have agency and peace of mind around their most sensitive data. When devices are equipped with access management, encryption, and security capabilities right out of the box, data is never exchanged between products without authenticating identity. Highly sensitive data can remain private, local to the IoT Gateway.	When a IoT Gateway is built with onboard compute capabilities powerful enough to coordinate, monitor, configure, and control multiple devices, new modes of self-service and support open up. Through voice-interaction, users can simply speak to control and configure their own network services, and solicit support requests through a convenient single-stop self-service portal.	The opportunity for innovation enabled through edge-level intelligence means products gain in value over time. For end-users, this translates into a single hardware investment which continuously delivers new features and services, constantly learns and adapts to user speech patterns and preferences, and evolves to support new use cases through open interoperability with any other device...on the body, in the home, or on the go.

BUSINESS-TO-BUSINESS: OPTIMIZATION THROUGH DISTRIBUTED AUTOMATION AND END-TO-END INTEGRATION

In the construct of balanced intelligence, where edge devices handle agile processing and new features, and where deeper learning and data mining occurs in the cloud, enterprises are poised to support improvement across every level of the product —and therefore customer— lifecycle. Most importantly, such a construct embeds innovation into service architecture, wherein open development environments enable new and diverse services to flourish.



1 AUTOMATIC IMPLEMENTATION	2 AUTOMATIC SERVICES ACTIVATION	3 INTEGRATED MANAGED SUPPORT SERVICES	4 UNIFIED ANALYTICS	5 BAKED-IN-INNOVATION
When in-field devices are outfitted for more robust local processing, enterprises enjoy a streamlined device installation process. Devices can automatically provision, certify, pair, and register themselves into Managed Service Provider (MSP) and Customer Relationship Management (CRM) systems.	Out-of-the-box configurations mean enterprise user registration, certification, and customer service activation is 'baked in' to the onboarding process. Such a gateway, for example, can automatically connect and troubleshoot to onboard nearby devices, and offer voice-enabled pairing for additional devices.	Enterprises' product and support programs also benefit from edge devices' ability to run preventative maintenance such as patch management, bug-fixing, anti-virus updates, and better manage incidents through remediation, customized help desks, integrated workflows and analytics via CRM integration.	When devices are enabled to interact in real-time, enterprises can parse and batch data to prioritize agility, while still gathering insights across data sets to learn over time. Integration with ERP, CRM, Finance, and other systems enables enterprises to unify analysis and machine learning with a single dashboard.	Product and service performance gain in efficiency as analytics and machine learning reveal areas to optimize such as connectivity, data transmission, and compute resources. For example, onboarding is improved over time as machine learning helps deliver better, more proactive support and troubleshooting to offload call center interactions.

Conclusion

The impact of edge-level compute ripples across the entire IoT value chain, redefining use cases and creating new opportunities at both the edge and cloud level. Balancing computational intelligence between the endpoints and the cloud means better agility to improve customer experience, drive leaner operations and cost efficiencies, and unlock more innovative ways of leveraging interconnectivity and services. For end-users, IoT is finally easy and user-centric; for enterprises, IoT services can finally launch and run on a global scale without the headache of complex configurations or rapidly evolving infrastructure requirements.

The open and adaptive real-time nature of IoT requires new types of value systems that can handle complex ecosystem-enabled business models. To monetize IoT-based services, individual companies will need to become orchestrators of value creation across partners, customers and open developer communities. If a company is unwilling or unable to participate, it will not be competitive in an IoT-driven world because its service will stay static.

Leveraging cloud capabilities and Web APIs solves frustrating interoperability problems between device protocols that keep value locked in the endpoints and limit user adoption. Devices that "talk to each other" drive interconnectivity between industries and allow enterprises to tap into the larger ecosystem of heterogeneous connected devices, significantly increasing revenue and cost optimization opportunities for both enterprises and their partners.

As companies become IoT data-driven information platforms, this also has a compounding '**network effect**' on the value created within the ecosystem. When ecosystem stakeholders share and enrich data across their ecosystems, the IoT will enable transformation of operational processes that results in improved customer experience and reduced operational costs.