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Digital Systems & Technology

Virtual Digital Surrogates & Blockchain: The Path Ahead for the IoT in the Sharing Economy

As concepts such as digital twins and machine-to-blockchain-powered smart contracts emerge for IoT-based businesses across the industrial world, they open the possibility for new borderless and ownerless ecosystems that will be driven by seamless collaboration and operational outcomes.

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Executive Summary

If history has taught us anything, it is that industrial paradigm shifts are inevitable and are bound to recur periodically. The scale of such shifts varies from the immense and intensively disruptive Industrial Revolution of the late 18^{th} and early 19^{th} centuries, to smaller yet significant disruptive developments such as the production of high quality, low-priced cars by Japanese automakers.

As the world becomes increasingly interconnected and instrumented with smart devices and technologies, industrial businesses are facing incredible churn. Both small and large industry players are struggling to find a clear and lucrative business model to better monetize the internet-connected devices that they either manufacture or use to enable production. A gathering wave of the sharing economy model is creating a paradigm shift in the consumption of Internet of Things (IoT) products and services.

Traditional transactions involve a transfer of ownership from a manufacturer or seller to a buyer. Typically, that is the end of the line for the manufacturer or vendor in the process of value creation. In the new sharing economy, however, the transfer of ownership is blurred, both for the manufacturer and the end consumer or user of the asset or its output. In a sharing economy, either the asset is a shared entity or the device/asset's output is portable. For example, a car is a physically portable asset that can be collaboratively consumed. In the case of a windmill, it is the asset's output – wind energy – that is shared.

The dual concepts of a digital twin and machine-to-blockchain networks are the key technology facilitators that enable industrial IoT devices to participate in the evolving sharing economy. These technologies play equally essential roles, from both a technical and commercial perspective. An efficient platform powered by such new-age technologies promises to offer a seamless user interface, generate real-time data to handle demand and supply, and enable smart, efficient and trusted ways of transacting among participating peers across the manufacturing value chain.

A digital twin is a virtual representation of a physical asset that is virtually indistinguishable from its physical counterpart. It includes design and engineering details that describe its geometry, materials, components, and behavior or performance. A digital twin can be associated with its physical product unit identifier such as an asset ID, equipment number, etc. The machine-to-blockchain component provides a way to conduct and record transactions through a peer-to-peer network that replaces the traditional role of a central trusted authority.

This white paper focuses on how IoT will play a role in converting lofty concept into business reality in the new sharing economy. It also proposes an innovative model to help industrial organizations internet-enable manufacturing operations via the concept of the digital twin to participate in the evolving sharing economy.

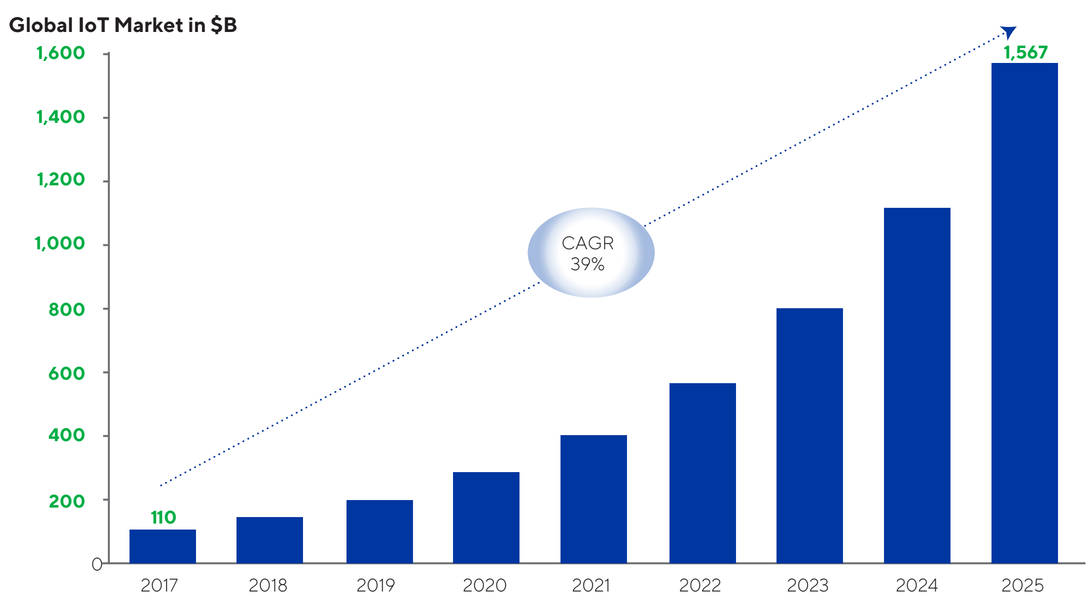
The IoT: Stealing the limelight

The IoT is quickly finding its way into mainstream applications as organizations realize its potential for improving operational efficiency. One key benefit is IoT-based predictive analytics derived from data the IoT collects and ingests in real time. Numerous, perpetually evolving business and monetization models are developing around the IoT. Accordingly, global market forecasts show a surge in end-user spending on IoT-based solutions. Due to the market acceleration for the IoT, estimates have been revised upwards, with the total market now expected to reach $1.567 trillion by 2025.

So far, the return on investment with IoT initiatives has not met expectations, due to fundamentally weak commercial models. IoT implementation challenges include:

- Network availability and latency.
- Expensive gears and sensors.
- Energy consumption.

Global IoT market forecast



Source: https://iot-analytics.com/state-of-the-iot-update-q1-q2-2018-number-of-iot-devices-now-7b/
Figure 1

As the digital era evolves, business models are gradually shifting. One emerging approach includes a service-based business model applied to individual IoT devices, which offers an auxiliary revenue stream based on usage or outcomes.

- Lack of user-centered design.
- Lack of standard legal and data protocols.

However, growing customer demands are pushing solution providers to create alternative and innovative business models, while addressing the above list of challenges. IoT players, particularly IoT device and/or component makers, have consistently offered product-based monetization models. This approach revolves around a one-time premium charge paid to the manufacturer or enabler during the purchase, and it also involves ultimate transfer of ownership.

As the digital era evolves, business models are gradually shifting. One emerging approach includes a service-based business model applied to individual IoT devices, which offers an auxiliary revenue stream based on usage or outcomes.

An IoT-based solar power plant, for instance, is an ideal candidate for creating a business model in which sharing economy principles can be applied to a service business model. Traditionally, the manufacturer's revenue depended on the number of devices sold for the power plant; it was not linked to each device's performance. However, with the emergence of the IoT sharing economy, the device manufacturer can now weave a service-based business model around the equipment. In this approach, the manufacturer capitalizes on the performance of the device – rather than handing over ownership of the device to the buyer. The buyer also benefits by utilizing the device based only on their requirement.

This new paradigm brings two key delivery enablers, one to virtually showcase and provide technical specifications of the IoT device to prospective customers, and the second to facilitate smart and secure monetary transactions. These two critical roles are played by digital twins and machine-to-blockchain technologies, respectively.

The digital twin plays the specification provider's role and the machine-to-blockchain component enables device commercialization (see page 13 for an example). This further creates a "peer-to-peer" trading approach with newer transactional modes such as cryptocurrencies and more.

Dealing with the new reality of the sharing economy

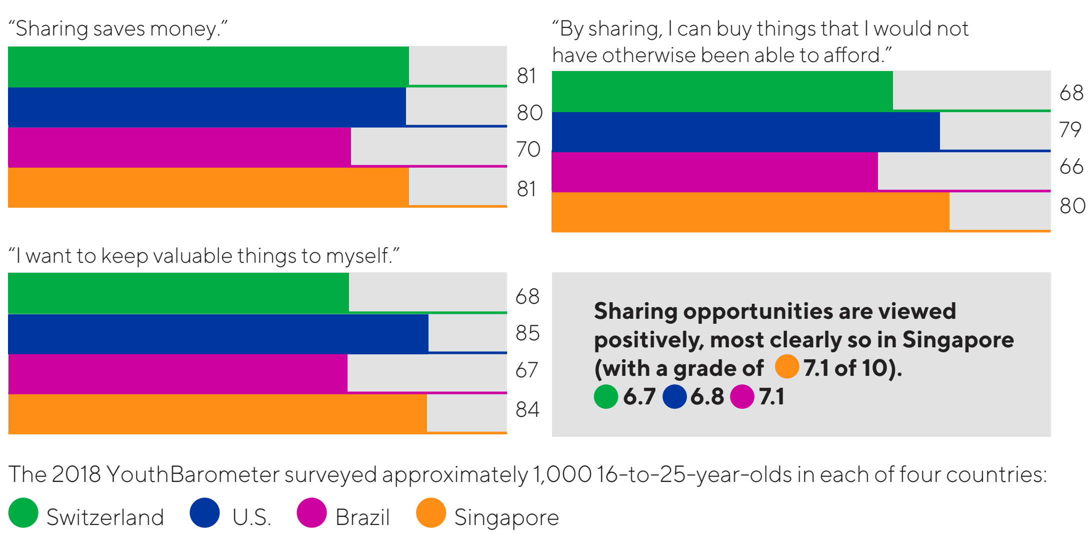
Market analysts indicate that platforms which provide access to shared goods and services are firmly established and poised to grow to an estimated $335 billion in the U.S. by 2025. The ongoing shift in car ownership in the consumer space (from cost to shared asset) offers numerous shared ecosystem possibilities in the industrial space – some realistic, others less so.

Applying shared economy principles to the generation of electricity, extra solar power generated either in a residential hub or an industrial plant can be shared with respective consumers based on demand. This enables energy producers to leverage their underutilized assets and monetize excess power generated by sharing the load with buyers who need energy. Device-sharing cases such as 3-D printers, vehicles, etc., are often-cited examples of the sharing economy.

The prime target audience for the sharing economy is the growing millennial population, between 18 and 25 years old. A considerable chunk of the millennial population has already used these collaborative consumption platforms at least once, according to a Credit Suisse survey, Youth Barometer Report 2018. The report also sheds light on several economic reasons, such as saving money, but also ideological

The sharing economy through millennial eyes

"To what extent do you agree with the following statements? (in percent)"



Source: Credit Suisse Youth Barometer Report 2018
Figure 2

ones, as this segment is keen to use existing resources sustainably. Figure 2 shows several questions and responses from the survey.

Building blocks of the sharing economy

For a potential asset to participate in the sharing economy, it must meet the following building blocks that together will enable a seamless transaction:

- Provide access to the asset via an application programming interface (API) to deliver a clearly defined set of outcomes.
- Offer visibility into commercial details pertaining to the transaction.
- Contain an e-commerce platform, which is fundamental to the business model.

As consumption shifts toward the sharing economy, the value of asset ownership gradually fades away. This transformation decouples the benefit and pain in this typically cumbersome transaction. The new untangled process provides multiple choices, cost savings and instantaneous availability of an asset or a service to the participating stakeholders.

Two sides of the sharing economy coin

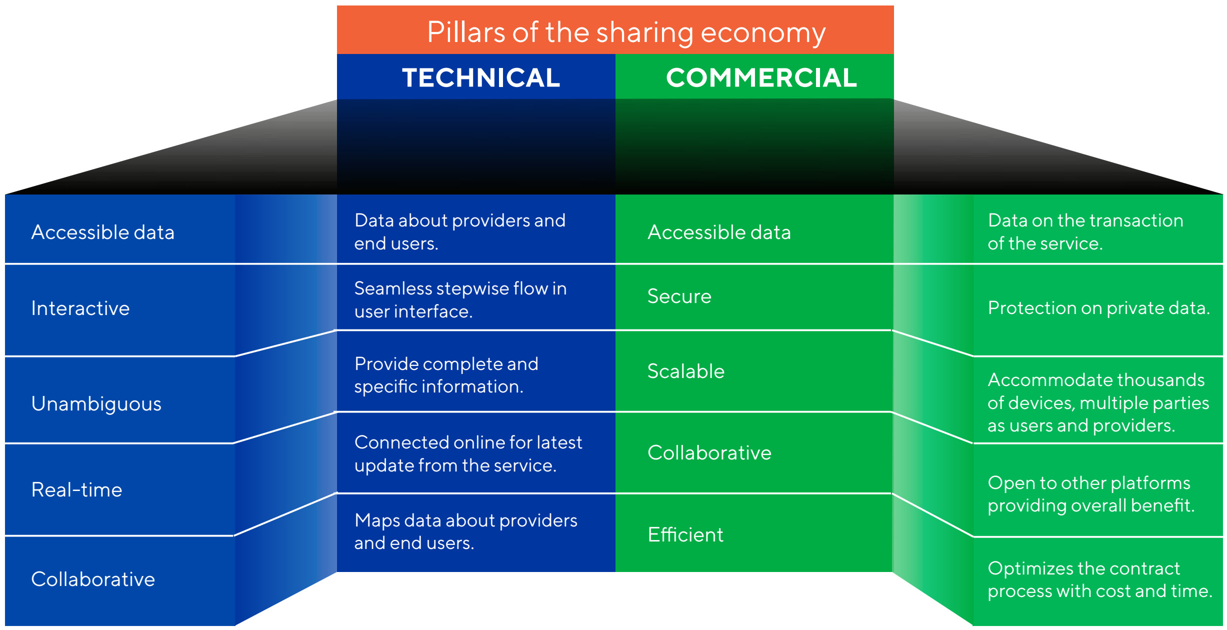


Figure 3

Digital twin: The technical enabler

In simple terms, a digital twin is a virtual surrogate of a physical object and its characteristics (see Figure 4). When extended, it can also predict future events and performances of an asset.

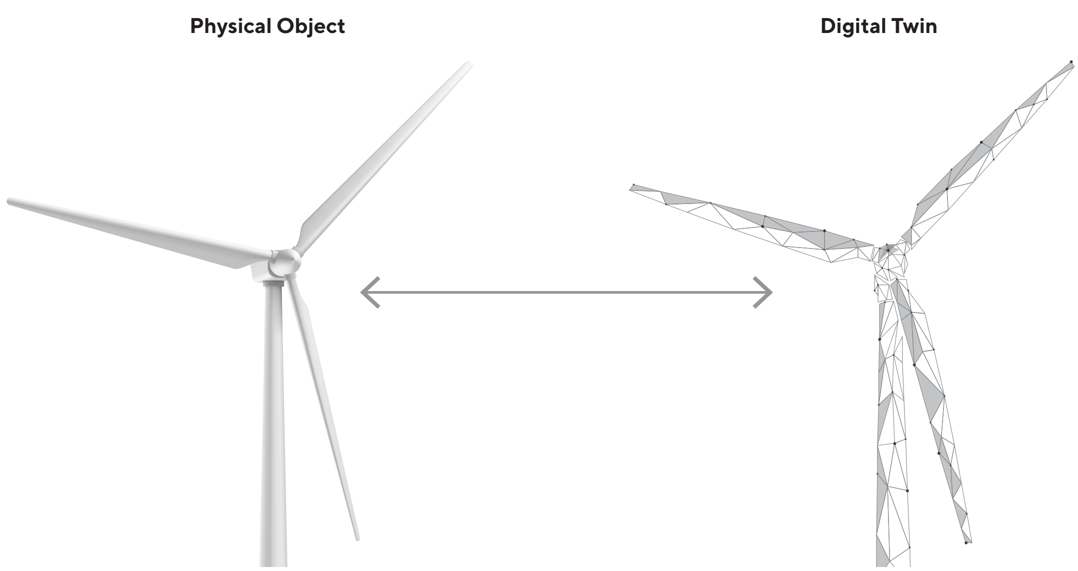
A digital twin is more than a blueprint and a schematic layout of an equipment. It is a virtual representation of the asset's characteristics and its dynamic behavior. Under operational conditions, as the equipment undergoes changes, these are captured and displayed to the user on a real-time basis.

The overall functional role of a digital twin is three pronged – observation, optimization and operational (see Figure 5, next page).

The multiple roles that a digital twin plays complement each other. Depending on the role they play, these virtual surrogates can be distributed across various deployment platforms.

As the optimization role involves simulation algorithms, the cloud is an appropriate infrastructure choice; in instances that require the twin to play an observational and/or an operational role, edge deployment is a natural preference, at either the gateway or device level.

Digital twin of a windmill: An artist's rendering



A digital twin is an encapsulated software object that mirrors a unique physical object's characteristics or a unique collection of physical objects.

Figure 4

The three-pronged role of a digital twin

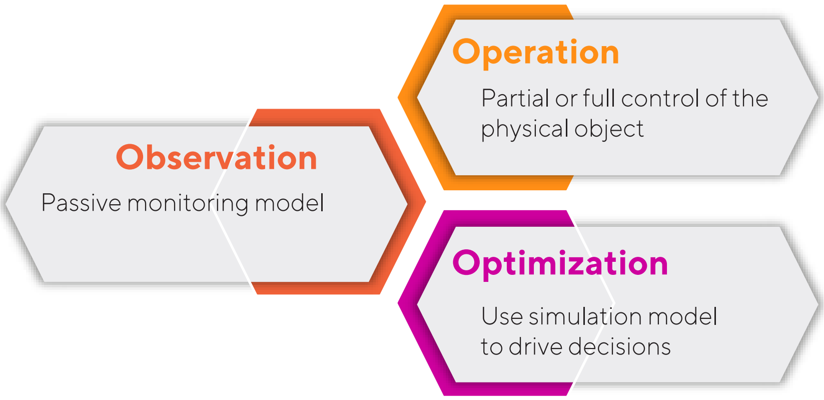


Figure 5

Digital twin technology promises to transform the way products are designed, built and operated across industries in the near future. For example, the manufacturing industry is now beginning to see the following impacts:

- **Design:** Operational insights contribute to better design. In a windmill power generation scenario, for example, detecting frequent wind direction variations at given sites will demand different kinds of support structures.
- **Build:** Continuous learning from these virtual twins helps manufacturers anticipate and avert glitches, and to further analyze and forecast results that might impact regular business.
- **Operate:** Informed service and support mechanisms yield better operations. For example, generating text messages/emails to inform users about scheduled services and part replacements can substantially reduce breakdowns.

For instance, in the case of a digital twin in an automobile-sharing ecosystem, the first step in this process is to create a virtual replica of the vehicle to be shared in a digital form. This will enable sharing of key specifications, such as make and model, current location, miles on the clock, color, accessories available, etc. In addition, the digital twin will also provide real-time data such as fuel status, noise levels, riding characteristics, nearest recharge station location, etc.

The digital twin is the software avatar of the physical version of the device, and is hosted in a cloud environment that can be accessed any time by peers (other digital twins, systems and platforms) with the necessary access permissions.

In a traditional business scenario, the buyer is typically reliant on the information that is provided by the asset owner. There is no information available directly from the device. The digital twin addresses this shortcoming by acting as a credible knowledge repository of the asset.

The dimensions of a digital twin

- **Granularity:** Although a digital twin is specific to a physical device, the granular nature of the device it represents defines the scale at which it can be put to use. A structural building as a whole can have a digital twin, wherein the identifiable parameters can be the block temperature, humidity, lighting, etc. This variation of the digital twin for a large physical asset can be classified as a coarse-grained version of the digital surrogate. A relatively fine-grained version can be that of an individual floor, aisle or a cabin within the larger structure. The latter type of the digital twin allows further drilling into more granular details based on individual sensors in the building.

Measuring a digital twin

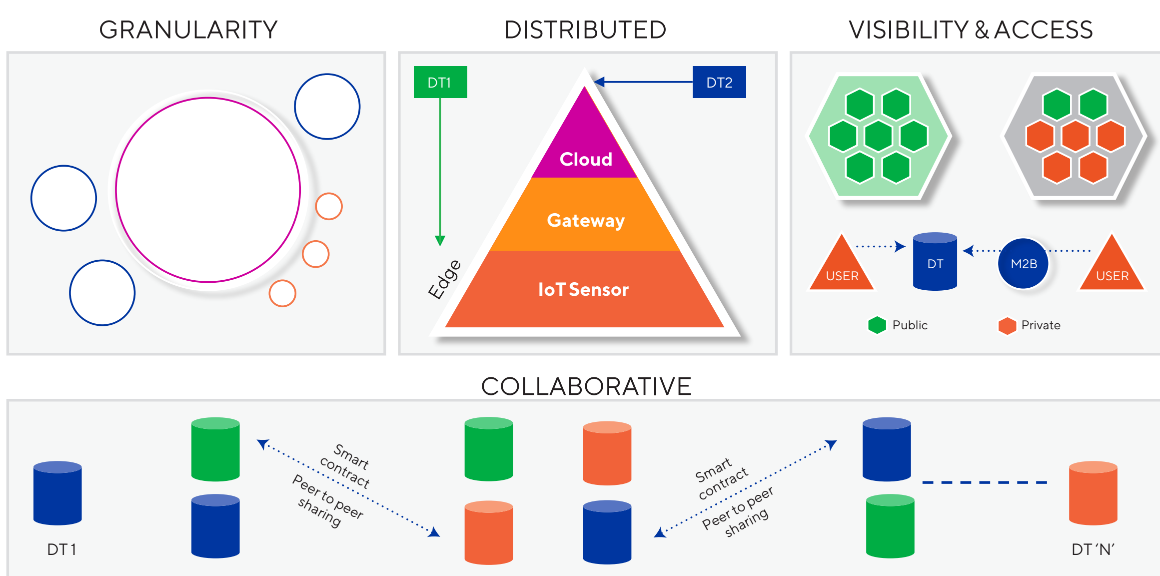


Figure 6

- **Distributed:** Details that a digital twin can provide should be made available at multiple points – wherever and whenever the information is requested. To enable this, a cloud-hosted environment is the preferred space. However, in cases where latency and scalability are critical, edge computing technology is a potential alternate. For example, a car as an asset can have its twin hosted in a cloud but the granular details that are closely tied to sensors in the vehicle must be hosted at the network's edge, to facilitate extensive information about the asset to a potential consumer.
- **Visibility and access:** A digital twin is flexible enough to be configured as a private or a public resource to benefit various participants in the sharing ecosystem. Based on the role performed by each user, appropriate access controls should be provided. This particular approach is critical for a sharing

A car as an asset can have its twin hosted in a cloud but the granular details that are closely tied to sensors in the vehicle must be hosted at the network's edge, to facilitate extensive information about the asset to a potential consumer.

economy, as multiple stakeholders involved require different types of access controls. For example, in the case of a shared windmill, the buyer will be keen to know much about the device's power output parameters, while maintenance- and production-related parameters will be lesser concerns. .

- **Collaborative**: With an increase in the number of digital twins in a given ecosystem,[7] these virtual avatars will need to interact with one another. This collaborative approach is potentially a strong driver for automation and peer-to-peer communication. For instance, an automobile's twin can talk to a gas station's twin 10 miles away to provide the user with helpful data – such as queuing status, fuel availability, types of fuel and current price.

All these dimensions augment the technical information in a business focused per asset model. This model can be continuously tuned, scaled and made adaptable to the growing needs of the IoT sharing economy.

In a traditional business ecosystem, commercial transactions are facilitated by single or multiple intermediaries such as vendors, agents, etc. Peer-to-peer (P2P) transactions, however, remove the need for intermediaries, benefitting both buyers and sellers via faster transaction times and improved transparency. However, it raises the challenge of how contracts can be effectively created and executed between parties, given the unique and diversified nature of each transaction in a sharing economy.

Playing this key role is the second facilitating component in this IoT sharing economy: machine-to-machine (M2M) smart contracts managed via blockchain networks. Further, blockchain's inherent advantageous attributes – such as records immutability, transparency and highly secured transactions – can reinforce the commercial integrity of any sharing economy transaction.

> Whenever an IoT device needs to create and participate in a payment transaction, blockchain's distributed ledger and public encryption techniques protect sensitive information while allowing data verification and authentication by all pertinent users.

Machine-to-blockchain: The commercial enabler

Peer-to-peer networks are an integral part of the sharing economy. Blockchain technology is a suitable candidate to achieve peer-to-peer sharing of assets because of its distributed, immutable and transparent nature. It enhances trust and security via its use of public key encryption. It also acts as a backbone for commercial transactions via shared infrastructure in a sharing economy, which eliminates redundancy and reduces costs.

A machine-to-blockchain smart contract is a derivative of the blockchain technology where the machines directly participate in transactional activities.

Machine-to-blockchain technology:

- Enables IoT ecosystems to break from the traditional middlemen-based networking paradigm, where devices rely on a central cloud server to identify and authenticate individual devices.
- Allows for the creation of secure networks, where IoT devices communicate commercial information to execute every transaction.
- Supports the formation of a network that is scalable to support billions of devices without the need for additional resources.

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Consider a case when a windmill gets a request of 10 Mw. Since the cluster of windmills belongs to an enterprise, a service level agreement (SLA) must be created to cover the overall terms of the contract. The requestor here can be a fellow enterprise, a government or a corporation. Once the SLA is mutually agreed upon, it is put into a private blockchain network. This ensures the contract is mutually accepted, transparent and secure. This can be understood as the first phase of the whole transaction.

The second level is operational in nature and deals with the actual sharing of information – i.e., energy transfer, which in this case is between the two entities. The operational process flow is depicted in Figure 7.

The stages of a blockchain-enabled transaction

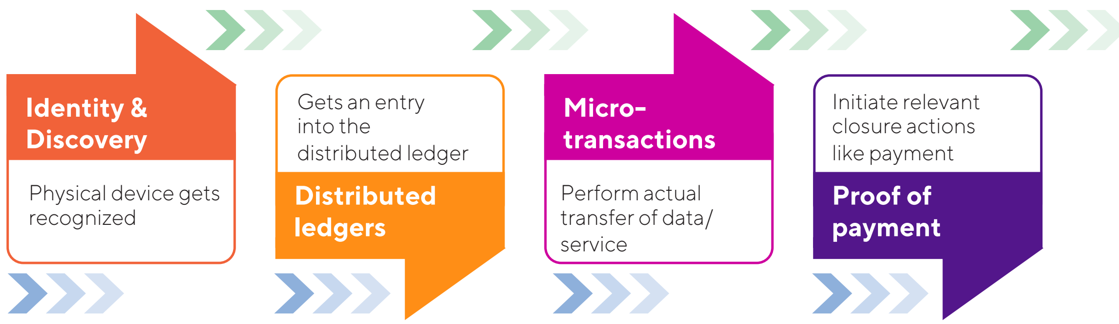

Figure 7

Characteristics of a sharing economy

Fundamental characteristics of the sharing economy, from a buyer's and seller's perspective, include the following:

For a buyer:

- **Flexibility and choices:** Provides a wider choice and introduces more flexibility on when and how they can plan or perform a transaction.
- **Transparency:** Parameters related to any specific transaction are completely shared with both the provider and the end user.

> The sharing economy is a perfect example of Metcalfe's network effect. The more players that enter into a market to leverage an underutilized asset, the greater the sharing economy impact.

- **Collaboration:** In a sharing economy, transactions are generally peer to peer and informal, and hence collaboration plays a key role in its success.
- **Trust:** There is consumption without exchange of ownership of any asset and this is possible only if all the players establish mutual trust.
- **Risk mitigation:** Buying the outcome or service of the shared asset is a key advantage for the buyer, as it reduces the risks associated with owning the asset.

For a seller:

- **Underutilization mitigation:** Enables the asset/service provider to leverage the potential of underutilized assets.
- **Top- and bottom-line enhancement:**
  - Increases revenue due to emergence of new business models.
  - Increases profitability through minimizing wastage by redistributing underutilized capacity.
- **Collaborative environment:** Creates new benefits in commercial and technical avenues for buyers, sellers and other parties in the ecosystem.
- **Scalability with a network effect:** With users incrementally joining the shared economy platform, the seller can scale at speed and benefit from the network effect produced.

The sharing economy is a perfect example of Metcalfe's network effect. The more players that enter into a market to leverage an underutilized asset, the greater the sharing economy impact.

Stages in sharing economy experience

Given the necessary building blocks and overall experience required to create a successful shared ecosystem, its workflow can be partitioned into two predominant stages (see Figure 8).

- **Stage 1: Joining the platform and sharing information:**
  - An individual or a device willing to be part of an existing sharing economy ecosystem needs to first join the platform.
  - Personal or device-specific information should be shared for authentication.
  - Once authenticated, the user starts fetching information from the provider, and the provider shares relevant user-specific information. A classic example is a cab booking scenario, wherein information like cab availability, travel destination, user's current location, ETA, calculated fare, etc. is shared.

Extending this to a generic scenario involving any IoT device participating in a sharing economy, relevant data from other parties (devices, platforms, third-party services, etc.) must be shared to interact and initiate a transaction. As noted above, the concept of the digital twin plays the role of the technology enabler in fetching and applying real-time data to observe, operate and optimize the performance of the physical device.

- **Stage 2: Transacting and consuming services:**
  - Once the required technical data is in place, the next step is commencing a transaction. This involves the user reserving a slot to either consume an existing service from other parties or share its own service to any requests coming in through the platform.
  - The following step consists of the actual consumption or sharing of services between two or multiple parties. A cab-sharing scenario, for instance, entails user delight at sharing a car based on need. Here, the actual sharing process and its completion is the transaction upon reaching the destination. For the cab driver, the ride fetches the compensation that moves him closer to his earning target.
  - Closure of the transaction requires that a payment mechanism is in place, and then the parties return to their original state.

Stages in user experience

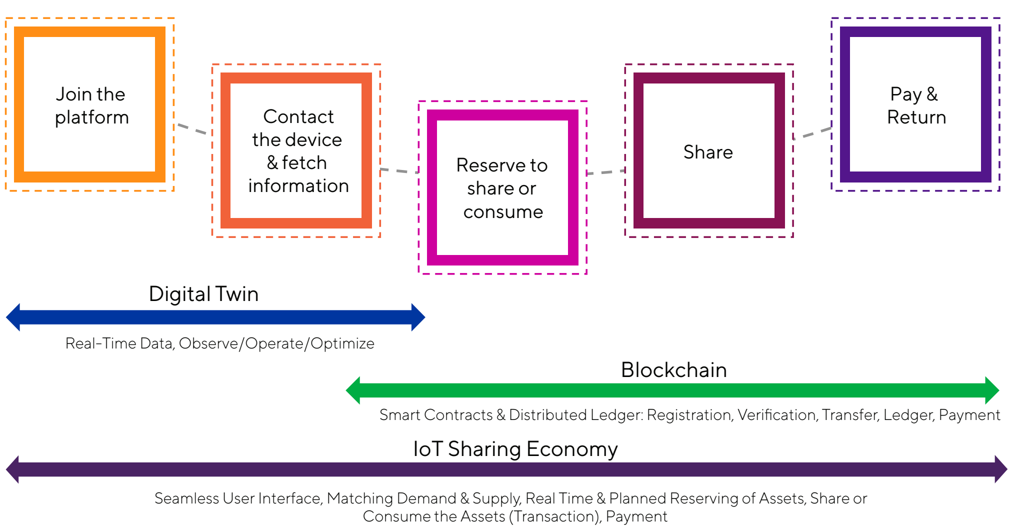

Figure 8

The IoT-powered future of the sharing economy

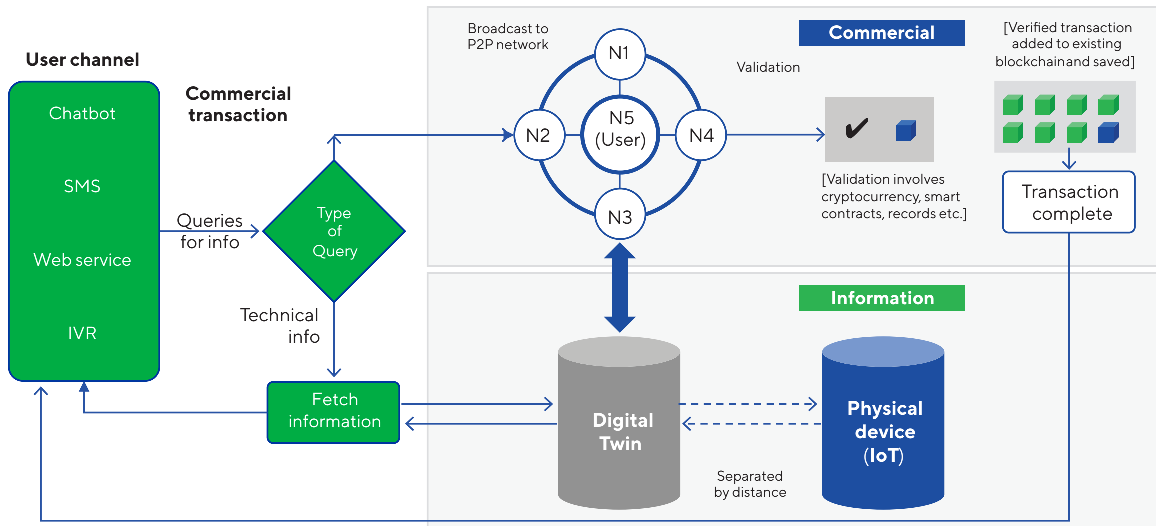

Figure 9

In light of the various changes occurring in the IoT space, it is clear that outcomes/results will become the rule of thumb for internet-enabled transactions in the future. This represents an outcome-based economy where enterprises have shifted from selling products and services to delivering measurable results to customers. This paradigm shift will need various parties in the ecosystem to adapt to delivering results transparently (see Figure 9).

The implications are large for businesses that choose to shift to an outcome-based economy. Such a move will require more precise data for calculating costs, managing risks and tracking all the factors involved in the delivery of promised value. New financial instruments such as smart contracts, cryptocurrencies, etc. will help enterprises manage the risks associated with guaranteeing outcomes.

To support such an evolving ecosystem, changes in pricing practices – such as pay performance based on output – are essential to reflect the enhanced value delivered. The IoT-based sharing economy model is supported by an ecosystem that is collaborative and advanced in terms of underlying technologies.

Success in this environment will require pooling and sharing real-time data in a dynamic atmosphere. It also demands greater cooperation among businesses, which will call for a more connected world comprising new market ecosystems and technology platforms.

Hence at an enterprise level, organizations must commit to making investments into cloud-based infrastructure to host digital twins and machines to blockchains, edge devices, etc. This can make real-time data accessible by end users via mobile apps. Digital twins and machine-to-blockchain technologies will play a critical role in defining the success of this emerging ecosystem.

The road to an outcome-based economy

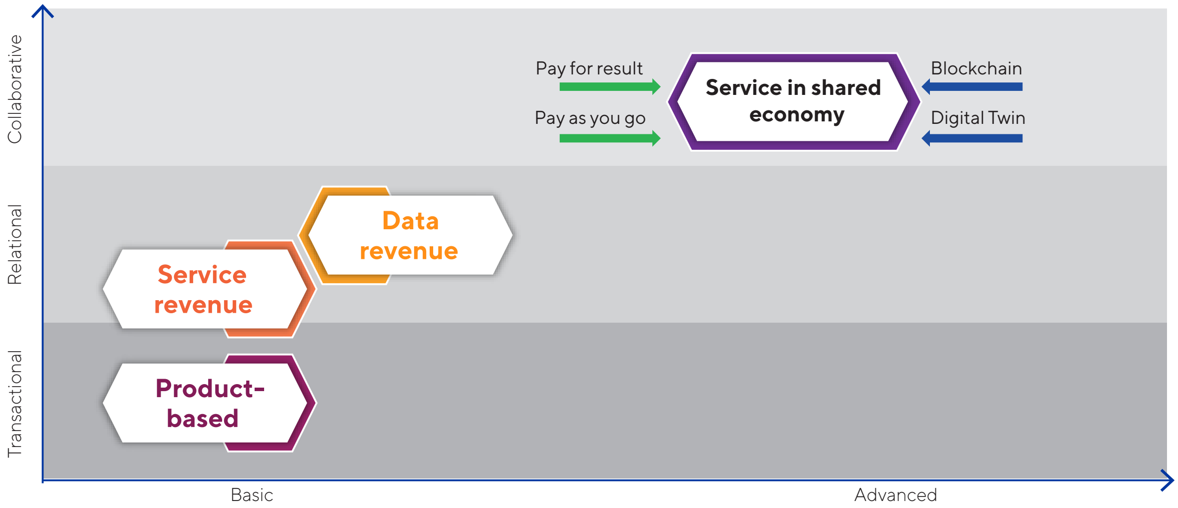

Figure 10

Looking ahead: The way forward for IoT

Since the Industrial Revolution, ever-accelerating technological change has provided a fulcrum for altering human lives. As the IoT sharing ecosystem evolves, with enabling technologies provided by digital twins and M2M blockchain networks, the business world is bound to move away from an asset-based economy and toward an outcome-based economy.

Going forward, we advise the following:

- All IoT device manufacturers will need to include the digital twin as a part of their deployment.
- A standard baseline mechanism to discover digital twins through online access will become mandatory.
- Blockchain service providers and systems integrators will need to provide smart contract templates to handle IoT devices and their virtual twins.

With such strong systems in place, ownership will lose relevance and access to shared assets could rule the day. This ease of access to any device at any point in time will impact what we do and how we do things in the near future, both in our professional and personal lives.

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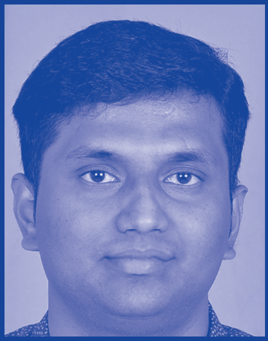

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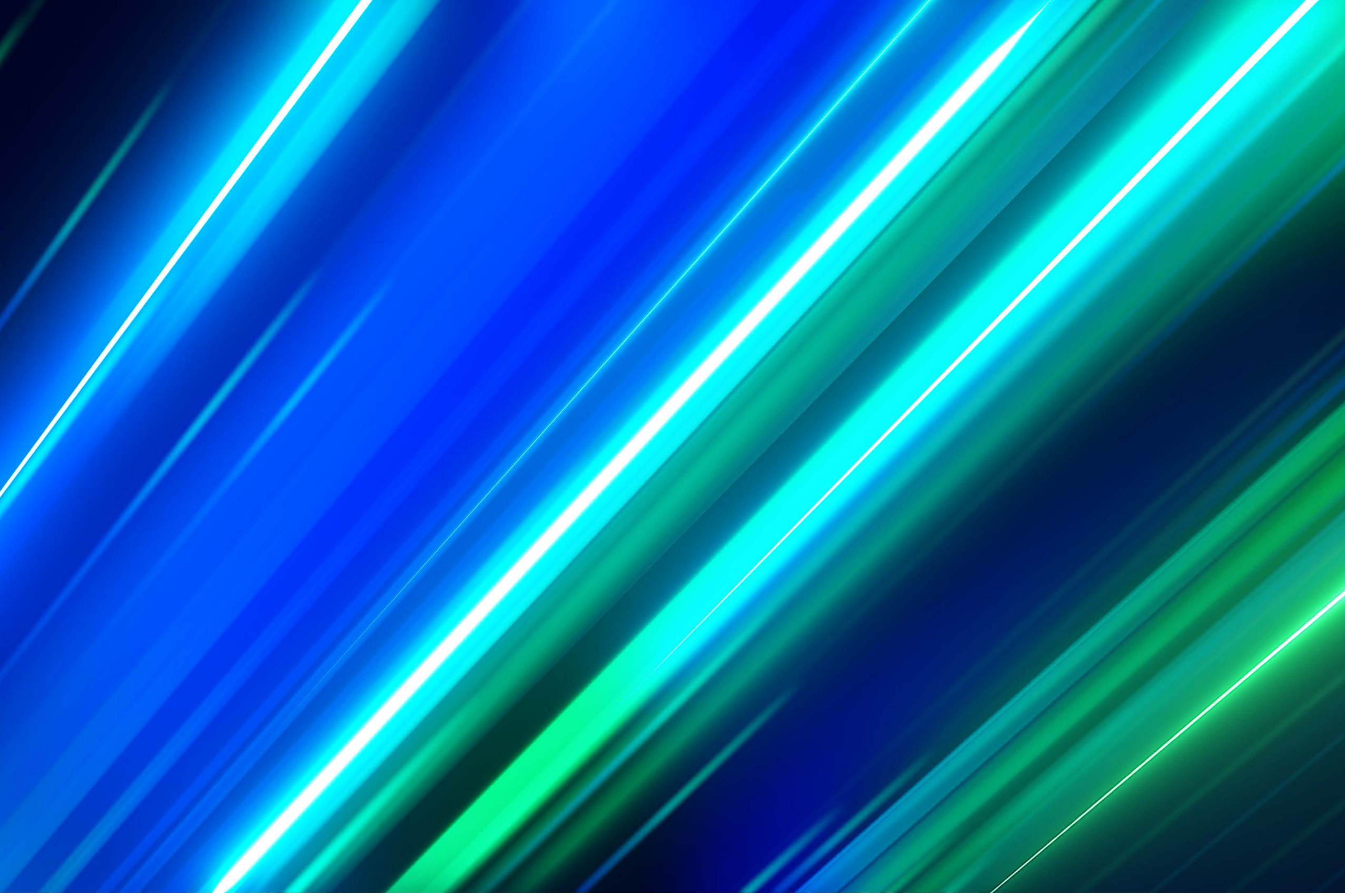

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