CHAPTER 6

THE LEDGER OF THINGS:

ANIMATING THE PHYSICAL WORLD

A power pole collapses at eight o'clock on a hot night in the remote outback of Australia. This is a problem for William and Olivia Munroe, who raise sheep and cattle one hundred miles outside the old gold mining town of Laverton, on the edge of the Great Victoria Desert.[1] In the summer, the temperature frequently soars close to 120 degrees Fahrenheit (48.9°C). Their children, Peter and Lois, attend school via satellite link, the family's only means of accessing health services in case of illness or emergency. Although the Munroes have a backup generator, it can't power the water pumps, communications, and air-conditioning for long. In short, the lives of the Munroe family depend entirely upon reliable energy.

At daybreak, nine hours later, the power utility sends out a team to find and fix the downed pole. Customer complaints give the company an idea of where the break occurred, but the team takes more than a day to identify, reach, and fix the pole. Meanwhile, the Munroes and nearby residents, businesses, and institutions go without power and connectivity at considerable inconvenience, economic impact, and physical risk. In the outback, blackouts are not just paralyzing; they're dangerous. To minimize these hazards, at great expense the company deploys teams of inspectors to check the extensive network regularly for downed or deteriorating poles.

Imagine how much safer, easier, and cheaper it would be if each power pole were a smart thing. It could report its own status and trigger actions for replacement or repair. If a pole caught fire or began to tip or fall for any reason, it would generate an incident report in real time and notify a repair crew to come with the appropriate equipment to the precise location. Meanwhile, the pole could potentially reassign its responsibilities to the nearest working pole. After all, they're all on the grid. The utility could restore power to the community more quickly without the huge ongoing costs of field inspection.

POWER TO THE PEOPLE

That's just the beginning. Using emerging software and technologies associated with the Internet of Things, we can instill intelligence into existing infrastructure such as a power grid by adding smart devices that can communicate with one another. Imagine creating a new flexible and secure network quickly and relatively inexpensively that enables more opportunities for new services, more participants, and greater economic value.

This configuration is known as a *mesh network*, that is, a network that connects computers and other devices directly to one another. They can automatically reconfigure themselves depending upon availability of bandwidth, storage, or other capacity and therefore resist breakage or other interruption. Communities can use mesh networks for basic connectivity where they lack access or affordable service. Mesh networks are alternatives to traditional top-down models of organization, regulation, and control; they can

provide greater privacy and security because traffic doesn't route through a central organization.[2]

Organizations are already combining mesh networks with blockchain technology to solve complex infrastructure problems. Filament, an American company, is experimenting with what it calls "taps" on power poles in the Australian outback. These devices can talk directly to each other at distances of up to 10 miles. Because the power poles are approximately 200 feet apart, a motion detector on a pole that's falling will notify the next pole 200 feet away that it's in trouble. If for any reason the tap on that pole isn't available, it will communicate with the next pole, or the next pole (up to 10 miles) that will communicate to the company through the closest Internet backhaul location (within 120 miles).

With the tap's twenty-year battery and Bluetooth low energy (BLE) technology, customers can connect to the devices directly with their own phone, tablet, or computer. The tap can contain numerous sensors to detect temperature, humidity, light, and sound, all of which customers could use to monitor and analyze conditions over time, maybe to develop predictive algorithms on the life cycle or impending failure of a power pole. Customers could become weatherNodes or meter these data as an information service or license the data set through the blockchain to another user, such as a government, broadcaster, pole manufacturer, or environmental agency.

Filament's business model is a service model involving three parties: Filament, its integration customer, and the utility company. Filament owns the hardware; its devices continually monitor the condition of the power poles and report changes, whether they're fallen, on fire, or compromised by dust accumulation or brush fire smoke. Filament sells the sensor data stream to the integrator, and this integrator sells to the utility.

The utility pays monthly for a monitoring service. The service enables the power company to eliminate the very expensive field inspection of its operations. Because power poles rarely fall, the power company rarely uses the actual communication capability of the mesh network, and so Filament could deploy the excess capacity of the taps for other uses.

"Since Filament owns the devices, we can sell extra network capacity on top of this network that spans most of the continent," said Eric Jennings, Filament's cofounder and CEO. "Filament could strike a deal with FedEx to give their semitrucks the ability to send telemetry data to HQ in real time, over our network in rural Australia. We add FedEx to the smart contract list, and now they can pay each device to send data on their behalf."[3] FedEx drivers could use the mesh network for communications and vehicle tracking across remote areas to indicate estimated arrival times and breakdowns. The network could alert the nearest repair facility to dispatch the necessary parts and equipment.

Blockchain technology is critical. This Internet of Things (IoT) application depends on a Ledger of Things. With tens of thousands of smart poles collecting data through numerous sensors and communicating that data to another device, computer, or person, the system needs to continually track everything—including the ability to identify each unique pole—to ensure its reliability.

"Nothing else works without identity," said Jennings. "The blockchain for identity is the core for the Internet of Things. We create a unique path for each device. That path, that identity, is then stored in the bitcoin blockchain assigned to Filament. Just like a bitcoin, it can be sent to any address."[4] The blockchain (along with smart contracts) also ensures that the devices are paid for so they continue to work. The Internet of Things cannot function without blockchain payment networks, where bitcoin is the universal transactional language.

Social Energy: Powering a Neighborhood

Now, instead of poles, imagine digitizing every node in a power system to create entire new peer-to-peer models of power production and distribution. Everyone gets to participate in a blockchain-enabled power grid. Under a New York State–sponsored program to increase energy resiliency even in extreme weather conditions, work is under way to create a community microgrid in the Park Slope area of Brooklyn. Once built, this microgrid and its locally generated power will provide resiliency in emergencies and reduce costs to customers while promoting clean, renewable electricity, energy efficiency, and storage options in the community.

While campus microgrids have been around for a while, they aren't common in residential areas. Most home owners, businesses, governments, and other organizations in urban North America get their power from regulated utilities at regulated prices. Currently, we have more variety in locally generated renewable energy from, say, solar panels on rooftops. The local utility captures excess power in its supply for redistribution at wholesale rates, often with considerable leakage. The consumer, who may be located across the street from a local power source, still must go through the utility and pay full retail for renewable energy generated by their neighbor. It's ridiculous.

"Instead of the command-and-control system the utilities have now where a handful of people are actually running a utility grid, you can design the grid so that it runs itself," said Lawrence Orsini, cofounder and principal of LO3 Energy. "The network becomes far more resilient because all of the assets in the grid are helping to maintain and run the utility grid."[5] It's a distributed peer-to-peer IoT network model with smart contracts and other controls designed into the assets themselves (i.e., the blockchain model).[6] When a hurricane destroys transmission towers or fire cripples a transformer substation, the grid can quickly and automatically reroute power to prevent a massive blackout.

Resiliency isn't the only benefit. Locally generated power, used locally, is significantly more efficient than the utility-scale model, which relies on transmitting energy across vast distances, where energy is lost. LO3 Energy is working with local utilities, community leaders, and technology partners to create a market where neighbors can buy and sell the local environmental value of their energy. "So, instead of paying an energy services company that's buying renewable energy credits, you get to pay the people who are actually generating the electricity that is serving your house, that is local and green, and that actually has an environmental impact in your neighborhood. It seems a lot fairer, right?" said Orsini.[7] Right!

If you can locate each of the assets and assign locational value for generation and consumption, then you can create a real-time market. According to Orsini, you can auction your excess energy to your neighbors who might not be able to generate renewable energy. In doing so, your community can create energy resiliency through peer-to-peer trading. Community members can reach consensus on the rules of the real-time microgrid market such as time-of-day pricing, floor or ceiling prices, priority given to your nearest neighbor, or other parameters so as to optimize price and minimize leakage. You will not be sitting at your computer all day long setting prices, offering to buy or sell.

Future microgrids will harvest heat from the computational power needed to create and secure this transactive grid platform. Distributing the computing power to buildings in the community and using the higher temperatures generated to power heating, hot water, and air-conditioning systems increases the productivity of the same energy. "Our focus is on increasing Exergy," says Orsini.

With increasing generation of renewable power at the local level, the Internet of Things is challenging the regulated utility model, and not a moment too soon. We need to respond to climate change and brace ourselves for increasingly extreme weather conditions, particularly melting ice caps that drown islands in oceans, and droughts that turn dry land into desert.

Currently, we're losing about fifteen million acres per year to desertification, the worst losses in sub-Saharan Africa where, unlike the Munroes of the outback, people can't afford water pumps, air-conditioning, or migration.[8] We need our utility grids and our engines not to leach energy and carbon into our atmosphere. While the utilities are looking at IoT benefits to their existing infrastructure ("smart grid"), connecting microgrids could lead to entirely new energy models. Utility companies, their unions, regulators, and policy makers, as well as innovative new entrants such as LO3, are exploring these new models for generating, distributing, and using electricity first at the neighborhood level and then around the world.

THE EVOLUTION OF COMPUTING: FROM MAINFRAMES TO SMART PILLS

Unlike our energy grid, computing power has evolved through several paradigms. In the 1950s and 1960s, mainframes ruled—International Business Machines and the Wild "BUNCH" (Burroughs, Univac, National Cash Register Corp., Control Data, and Honeywell). In the 1970s and 1980s, minicomputers exploded onto the scene. Tracy Kidder captured the rise of Data General in his 1981 best seller *The Soul of a New Machine*. Like mainframe companies, most of these firms exited the business or disappeared. Who remembers Digital Equipment Corporation, Prime Computer, Wang, Datapoint, or the minicomputers of Hewlett-Packard or IBM? In 1982, IBM hardware and Microsoft software brought us the decade of the PC, with Apple's Macintosh barely nipping at their heels. How things change.

Driven by the same technological advances, communications networks evolved, too. From the early 1970s, the Internet (originating in the U.S. Advanced Research Projects Agency Network) was evolving into its present-day, worldwide, distributed network that connects more than 3.2[9] billion people, businesses, governments, and other institutions. The computing and networking technologies then converged in mobile tablets and handhelds. BlackBerry commercialized the smart phone in the early aughts, and Apple popularized it in the iPhone in 2007.

What is relatively new and very exciting is the ability of these devices to go beyond relatively passive monitoring, measuring, and communicating (weather patterns, traffic patterns) to sensing and responding; that is, executing a transaction or acting according to predefined rules of engagement. They can sense (falling temperatures, traffic jams) and respond (turn on the furnace, lengthen the green light); measure (motion, heat) and communicate (emergency services); locate (burst water main) and notify (repair crews); monitor (location, proximity) and change (direction); identify (your presence) and target (market to you), among many other possibilities.

The devices can be static (poles, trees, pipelines) or mobile (clothing, helmets, vehicles, pets, endangered animals, pills). Caregivers are using smart —or edible—electronic pills, for example, to identify and record whether and when a patient takes his medication. A skin patch or tattoo captures the data and can measure heart rate, food consumption, or other factors and communicate this information to a physician, caregiver, or the patient himself through an app to identify patterns and give feedback. The medical profession will soon be using similar technology for targeted drug delivery to certain types of cancer, measuring core temperature and other biomarkers.[10]

The devices can communicate with one another, with computers and databases directly or through the cloud, and with people (send you a text message or call your mobile). These devices, through their evolving machine intelligence and the data they collect, are putting analysis of data, pattern

recognition, and trend spotting into individual hands.[11] The industry term *big data* hardly describes the myriad data that the physical world will generate. By the most conservative estimate, the 10 billion or so devices connected via the Internet today will grow to more than 25 billion by 2020.[12] Call it "infinite data" from infinite devices.

So why don't we live in smart homes and drive smart cars and practice smart medicine? We see six big obstacles. One is the Rube Goldberg rollout of applications and services. Simply put, few of the early consumer IoT devices have delivered practical value, unless you want your smoke detector to ask your night light to call your smart phone and warn you of a fire.[13]

Another is organizational inertia and the unwillingness or inability of executives, industry associations, and unions to envision new strategies, business models, and roles for people. While some creative entrepreneurs have developed new businesses on some of these principles (i.e., enabling physical assets to be identified, searched, used, and paid for) and thereby disrupted existing markets (e.g., Uber, Airbnb), the impact is still comparatively minor and reliant upon a company and its app as intermediary.

A third is fear of malicious hackers or other security breaches that could modify the information and rules of engagement, overriding devices with potentially disastrous consequences. A fourth is the challenge of "future-proofing," critical for capital things with very long life spans, longer than the life span of a typical application or even a company. Start-ups go bankrupt or sell themselves to larger firms all the time.

A fifth is scalability; to realize the full value of the IoT, we must be able to connect multiple networks together so that they interoperate. Last is the overarching challenge of centralized database technology—it can't handle trillions of real-time transactions without tremendous costs.

To overcome these obstacles, the Internet of Everything needs the Ledger of Everything—machines, people, animals, and plants.

THE INTERNET OF THINGS NEEDS A LEDGER OF THINGS

Welcome to the Internet of Everything enabled by the Ledger of Everything—distributed, reliable, and secure information sharing, sensing, and automating actions and transactions across the Internet, thanks to blockchain technology. Technologists and science fiction writers have long envisioned a world where a seamless global network of Internet-connected sensors could capture every event, action, and change on earth. With ubiquitous networks, continued advancements of processing capability, and an increasing array of cheap and tiny connected devices, that vision of an "Internet of Things" is edging closer to reality.

Remember, Satoshi Nakamoto designed the bitcoin blockchain to ensure the integrity of each bitcoin transaction online and the bitcoin currency overall. By recording each transaction at every node and then sharing that record with every other node on the network (i.e., the blockchain), the blockchain ensures that we can verify the transaction quickly and seamlessly across the peer-to-peer network. We can conduct transactions of value—in this case financial—automatically, securely, and confidently without needing to know or trust each node on the network, and without going through an intermediary. The Ledger of Everything requires minimal trust.

Blockchain technology enables us to identify smart devices with relevant core information and program them to act under defined circumstances without risk of error, tampering, or shutting down in the Australian outback. Because the blockchain is an incorruptible ledger of all data exchanges that occur in the network, built up over time and maintained by the collaboration of nodes in that particular network, the user can be sure the data are accurate.

There is growing agreement among technology companies that the

blockchain is essential to unlocking the potential of the Internet of Things. None other than IBM, the progenitor of large, centralized computer systems, has come on board. In a report, "Device Democracy: Saving the Future of the Internet of Things," IBM identified the value of the blockchain:

> In our vision of a decentralized IoT, the blockchain is the framework facilitating transaction processing and coordination among interacting devices. Each manages its own roles and behavior, resulting in an "Internet of Decentralized, Autonomous Things"—and thus the democratization of the digital world . . . devices are empowered to autonomously execute digital contracts such as agreements, payments and barters with peer devices by searching for their own software updates, verifying trustworthiness with peers, and paying for and exchanging resources and services. This allows them to function as self-maintaining, self-servicing devices. . . . [14]

Therefore, by using the blockchain, whole new business models open up because each device or node on the network could function as a self-contained microbusiness (e.g., sharing power or computing capability at very low cost).

"Other examples are a music service, or an autonomous vehicle," noted Dino Mark Angaritis, founder of Smartwallet. "Each second that the music is playing or the car is driving it's taking a fraction of a penny out of my balance. I don't have a large payment up front and pay only for what I use. The provider runs no risk of nonpayment. You can't do these things with traditional payment networks because the fees are too high for sending fractions of a penny off your credit card."[15]

Spare bedrooms, empty apartments, or vacant conference rooms could rent themselves out. Patents could license themselves. Our e-mail could charge spammers for each item received. You get the idea. With machine learning, sensors, and robotics, autonomous agents could manage our homes and office buildings, interactive sales and marketing, bus stop shelters, traffic flow and road usage, waste collection and disposal (i.e., where the bins speak to the trucks), energy systems, water systems, health care devices embedded or worn, inventories, factories, and supply chains.

Carlos Moreira, CEO of WISeKey, said that the greatest opportunities lie in what he called the *industrial blockchain*.[16] WISeKey, a Swiss-based company working in the area of identity management, cybersecurity, and mobile communications, provides secure transactional capability to watches and other wearable devices and is now offering its trust model to manufacturers and chip makers for outfitting a very large number of other IoT devices to be authenticated and to communicate across the Internet or other network. "We are moving into another world where the trust is delegated at the object level. An object that is not trusted will be rejected by the other objects automatically without having to check with a central authority," Moreira said. "This is a huge paradigm shift that has tremendous consequences in the way that processes will be conducted in the years to come."[17]

In this emerging world, users connect with smart devices using secure identification and authentication, potentially public/private keys, and they define the rules of engagement, such as privacy, with other devices, rather than going along with the rules of a centralized node or intermediary. Manufacturers can transfer maintenance, ownership, access, and responsibility to a community of self-maintaining devices, future-proofing the IoT and saving infrastructure costs, replacing each device exactly when it hits obsolescence.

Thus the blockchain can address the six obstacles to a functioning Internet of Things. To sum up, the new Ledger of Everything has nine nifty

network features:

Resilient Self-corrects; no single point of failure
Robust Can handle billions of data points and transactions
Real-time Stays on 24/7/365 and data flows instantly
Responsive Reacts to changing conditions
Radically open Constantly evolves and changes with new input
Renewable Can be multipurpose, reused, and recycled
Reductive Minimizes costs and friction, maximizes process efficiency
Revenue-generating Enables new business models and opportunities
Reliable Ensures integrity of data, trustworthiness of participants

Why do we believe the IoT enabled by the blockchain has such huge potential? The primary driver is that it allows *animation* of the physical world. Once we bring these objects to life on the ledger, they can sense, respond, communicate, and take action. Assets can search, find, use, and compensate one another according to smart contracts, thereby enabling highly disruptive new markets, just as the Internet has previously done for people and all manner of digital content.

The questions for managers, entrepreneurs, and civic leaders: How will you take advantage of these new opportunities to change and grow? How will your organization respond to the inevitable disruption to your existing operational model? How will you compete with the creative new models of start-ups and collaborations?

Opportunities for greater efficiency, improved service, reduced costs, increased safety, and better results abound in our lives, and we can improve each by applying blockchain logic to the Internet of Things. We're beginning the next major phase of the digital revolution. Michelle Tinsley of Intel explained why her company is deeply investigating the blockchain revolution: "When PCs became pervasive, the productivity rates went through the roof. We connected those PCs to a server, a data center, or the cloud, making it really cheap and easy for lean start-ups to get computer power at their fingertips, and we're again seeing rapid innovation, new business models."[18] Intel wants to accelerate the process of understanding what's working, what's not working, and where the opportunities lie. "We could see this technology be a whole other step function of innovation, where it enables all sorts of new companies, new players. To be a leader in the technology industry, we cannot be absent from the conversation," she said.[19] Just imagine the potential of applying these capabilities across many types of businesses, many untouched by the Internet revolution.

THE TWELVE DISRUPTIONS: ANIMATING THINGS

What possibilities are there for animating the physical world? Unlike Pinocchio, we don't have a Blue Fairy. (And unlike Pinocchio, the blockchain doesn't lie.) But today, right now, we have distributed ledger technology that will actually enable not only GE to "bring good things to life." Even better, Pinocchio can't go long-nose on the ledger.

We're in the early days of thinking about the possibilities of the Ledger of Everything (built into the IoT). While consumer devices have received the most attention in the popular media to date, there are potential applications across virtually every sector. There are many ways of classifying and grouping potential applications because so many applications cross boundaries and could fit into more than one category. McKinsey, for example, uses the concept of *settings* in its classification of the IoT.[20] We've identified

opportunities for the Ledger of Everything in twelve major functional areas. Specific benefits—and the business case—will be specific to each application. The categories below illustrate the potential and the potential significant disruption to existing markets, players, and business models.

1. Transportation

In the future, you'll call up an autonomous vehicle to get you safely where you need to go. It will intuitively take the fastest route, avoid construction, handle tolls, and park all on its own. In times of traffic congestion, your vehicle will negotiate a *passing rate* so that you arrive at your destination on time, and freight managers will use the blockchain-enabled IoT on all cargo to clear customs or other required inspections quickly. No red tape. Allianz, a manufacturer of street sweepers, could equip its municipal machines with minicam or sensor technology that identified cars whose owners hadn't moved them (if they couldn't move themselves) on alternate-side-of-the-street-parking days in New York City, feed that sensor data to the traffic police, and spare the physical writing of parking tickets. Or, the street sweeper itself could extract the parking fine in bitcoin from the car itself as it swept by—because the New York State Department of Transportation would require all cars registered in the five New York City boroughs to maintain bitcoin wallets connected to their license plates. Autonomous vehicles, on the other hand, would sense the oncoming sweeper and simply move themselves to let it pass.

2. Infrastructure Management

Many professionals will use smart devices to monitor location, integrity, age, quality, and any other relevant factors of pavement, rail lines, power poles and lines, pipelines, runways, ports, and other public and private infrastructure in order to monitor conditions, detect problems (e.g., breakage or tampering), and initiate a response both rapidly and cost-effectively. That's where companies such as Filament will come in, with new affordable technologies to animate existing infrastructure without the huge capital required to replace it. Eric Jennings of Filament estimates that "over 90 percent of infrastructure is currently disconnected, and it's unfeasible to rip it all out and replace it with brand-new, wireless, connected assets."[21]

3. Energy, Waste, and Water Management

"Send a truck to empty me," said the overflowing waste bin. "Fix me," said the leaky pipe. The Internet of Things should inspire a hundred new children's books. Traditional utilities in both the developed and developing world can use the blockchain-enabled IoT for tracking production, distribution, consumption, and collection. As we've already seen, new entrants without significant embedded infrastructure are planning to use these technologies to create entirely new markets and new models (e.g., community microgrid).

4. Resource Extraction and Farming

Cows can become blockchain appliances, enabling farmers to track what the cows eat, which medications they've had, and their complete health history. This technology can also help track expensive and highly specialized equipment and make it more widely available for just-in-time usage and cost recovery; improve miner and farmworker safety through tagging of safety equipment and automated checklists (to ensure that equipment is being used properly); monitor weather, soil, and crop conditions to start irrigation, automated harvesting, or other actions; and compile "infinite data" analytics to identify new resources or advise on agricultural best practices based on past patterns and results. Sensors in soil and on trees could help environmental protection agencies to monitor farmers and their usage of the land.

5. Environmental Monitoring and Emergency Services

Remember autonomous weather agent BOB? BOB will live in a world of weather sensors and make money collecting and selling critical weather data. Examples here include monitoring air and water quality and issuing alerts to reduce pollutants or stay indoors; flagging dangerous chemicals or radioactivity for emergency workers; monitoring lightning strikes and forest fires; installing earthquake and tsunami early warning and alert systems; and, of course, storm monitoring and early warning. In addition to improving the response time for emergency services and reducing the risk of these events to human life, we could use this longitudinal data to increase our understanding of underlying trends and patterns, identify preventive measures in some cases, and improve our predictive capability to provide even earlier warning.

6. Health Care

In the health care sector, professionals use digitization to manage assets and medical records, keep inventory, and handle ordering and payments for all equipment and pharmaceuticals. Today, hospitals are full of smart devices that oversee these services, but few communicate with one another or take into account the importance of privacy protection and security in direct patient care. Blockchain-enabled IoT can use emerging applications to link these services. Applications in development include monitoring and disease management (e.g., smart pills, wearable devices to track vital signs and provide feedback) and improved quality control. Imagine an artificial hip or knee that monitors itself, sends anonymized performance data to the manufacturer for design improvements, and communicates with a patient's physician, "Time to replace me." Technicians will be unable to use specialized equipment if they haven't taken prerequisite steps to ensure their reliability and accuracy. New smart drugs could track themselves in clinical trials and present evidence of their effectiveness and side effects without risk of modified results.

7. Financial Services and Insurance

Financial institutions could use smart devices and the IoT to tag their claims on physical assets, making them trackable and traceable. Because digital currencies enable the storage and transfer of value rapidly and securely for all users large and small, they also enable risk assessment and management. Thinking further, could the poor and disadvantaged earn small amounts of cash, or perhaps electricity or other "credits," if they allowed their limited assets to be tagged and shared as in the earlier microgrid example? Owners will be able to tag priceless objects, antiquities, jewelry, the stuff of museums, anything ever handled by Sotheby's and insured by Lloyd's. Insurers could adjust payment according to where the object is and its environment—if it's in New York's Metropolitan Museum of Art under controlled climate, then a lower insurance rate; if traveling to Greece, then charge a higher rate. The object could tell whether it was in a vault or around a celebrity's neck. Insurance rates could be higher if the device was hanging on Lindsay Lohan's neck versus, say, Anne Hathaway's. Driverless cars would surely have lower insurance rates, and devices themselves could settle insurance claims on the spot based on sensor data.

8. Document and Other Record Keeping

As we have explained, physical assets can become digital assets. All documentation relating to a particular "thing" can be digitized and carried on the blockchain including patents, ownership, warranties, inspection certification, provenance, insurance, replacement dates, approvals, et cetera, significantly increasing data availability and integrity, reducing paperwork

handling, storage, and loss, and other process improvements related to that documentation. For example, a vehicle will not start if it failed a recent safety inspection, if its liability insurance has expired, if its owner has failed to pay parking tickets or moving violations, or if the driver's license of the person attempting to drive it has been suspended. Items on the shelves will notify store managers when they've passed their "sell by" date. Store managers might even program these items to lower their own price as the sell-by date approaches.

9. Building and Property Management

An estimated 65 percent of the twelve billion square feet of commercial real estate in the United States is vacant.[22] Digital sensors can create marketplaces of these real estate assets by enabling real-time discovery, usability, and payment. Vendors are now entering this field and developing new service models to rent the space in off hours. In the evenings, your conference room can moonlight as a classroom for neighborhood youth or an office for a local start-up. Other applications will include security and access control, lighting, heating, cooling, and waste and water management. The greenest of buildings will run on the Ledger of Things. Imagine the data on elevator usage and flow of people through the building, how these will inform an architect's design of public and private spaces. Spare residential space can list itself and negotiate through the Ledger of Everything to help tourists, students, managers of homeless shelter programs, and others find space that meets their needs. These ideas apply to all types of residential, hotel, office, factory, retail/wholesale, and institutional real estate.

10. Industrial Operations—The Factory of Things

The global plant floor needs a global Ledger of Things, aka the industrial blockchain. Factory managers will use smart devices to monitor production lines, warehouse inventory, distribution, quality, and other inspections. Entire industries may adopt the ledger approach to significantly increase efficiency for such processes as supply chain management. Large and complex machines, like airplanes and locomotives, consist of millions of parts. Each individual component of a jet engine or railcar could have sensors that send out an alert when it needs fixing. Imagine a train on its way from Baltimore to Long Beach notifying the maintenance crew in Long Beach three days ahead of time that it needed a critical new part. The sensor could even issue an RFP and accept the best bid and delivery for the part, cutting time and massive cost out of the operating efficiencies of large corporations like General Electric, Norfolk Southern, and others. Even more significant, manufacturers in realms from cars to light bulbs to Band-Aids are investigating how they can embed smart chips into their products or parts thereof and monitor, collect, and analyze performance data. With such data, they could provide automatic upgrades, anticipate client needs, and offer new services, in effect changing from product suppliers to ongoing software-based services.

11. Home Management

Feeling lonely? You can always talk to your house. Your own home and numerous products and services are entering the market to allow automated and remote home monitoring. These services go beyond the "nanny cam" to include access controls, temperature adjustments, lighting, and, eventually, just about everything else in your home. While "smart homes" have been relatively slow to take off, companies such as Apple, Samsung, and Google are working to simplify installation and operations. According to BCC Research, "The U.S. home automation market is estimated to go from almost $6.9 billion in 2014 to $10.3 billion in 2019 . . . the growth will be steady and long-term."[23]

12. Retail Operations and Sales

Walking down the street, your mobile device advises you that the dress you love is available at the Gap. Walk into the store and the dress, in your size, is waiting for you. After trying it on, you scan it and the payment is complete. But you've got other things to do, so the dress finds its way to your house before you get home. In addition to operational efficiencies and environmental monitoring, retailers will be able to personalize products and services to identifiable customers as they walk or drive by based on their location, demographics, known interests, and purchasing history, provided that those customers opened their black boxes to retailers on the blockchain.

THE ECONOMIC PAYOFF

Throughout this chapter we've referenced numerous potential benefits of the distributed, blockchain-enabled IoT at many levels (individual, organizational, industrial, societal). Redesigning and automating processes across peer-to-peer networks, rather than through people or centralized intermediary apps, could bring numerous benefits as already identified including:

- Speed (end-to-end automation)
- Reduced costs (associated with sending nearly infinite amounts of data to giant central processing facilities; elimination of expensive intermediaries)
- Increased revenue, efficiency, and/or productivity (freeing up excess capacity for reuse)
- Improved effectiveness (built-in checklists and other protocols reduce impact of human error)
- Increased security and integrity (person-to-person trust is not required as trust is designed into the network architecture)
- Reduced likelihood of system failure (elimination of bottlenecks, built-in resiliency)
- Reduced energy consumption (energy required by the network itself offset by increased efficiency and reduced wastage, dynamic pricing, and feedback loops)
- Increased privacy protection (intermediary can't override or ignore rules defined in the blockchain)
- Improved understanding of underlying patterns and processes and opportunities to improve them through the collection and analysis of "infinite data"
- Strengthened predictive capability of various events whether negative (severe weather, earthquakes, failing health) or positive (best time to plant crops, buying patterns).

The distributed open model means that IoT networks can be self-sustaining even after a company pulls out or a manufacturer fails. Interoperability, when designed into the system, will enable the connecting of different IoT networks and will unleash even greater value.[24]

Many of these benefits depend upon the concepts of distributed, or decentralized, networks and the elimination of a central (e.g., command and control) or other intermediary (e.g., a clearinghouse or management app). Once these new intermediaries are in place, others will feel pressure to "work around" or eliminate them. In Eric Jennings's view, "People will do the things they'll do to minimize their own discomfort, leading to silos and concentration and centralization. What's a short-term gain for those particular people is a long-term loss for everyone else." He said, "The Internet of Things should be completely decentralized where devices can be autonomous, discover each other directly, establish secure communication with each other directly, and eventually pay each other in value, directly between machines."[25]

The IBM Institute for Business Value has conducted research into what it calls the five major "vectors of disruption" that will increase our leverage of physical assets as the result of the blockchain-enabled IoT.[26] While IBM clearly has a business interest in the IoT, its work on business value is nonetheless very helpful.

First, the institute noted that these new networks will enable users to instantly search, access, and pay for available physical assets, such as underutilized storage or computing capability. The assets in supply can match themselves to demand. Because we can assess risk and credit automatically online and repossess virtually, we can reprice credit and risk significantly downward. Automated usage of systems and devices improves operational efficiency. Finally, firms can crowdsource, collaborate, and optimize with business partners in real time through digitally integrated value chains.

In short, you have an opportunity to make conceptually simpler, more efficient markets. You can access previously inaccessible assets, determine price in real time, and reduce your risk. Once the basic infrastructure is in place, barriers to entry are low (e.g., just develop an app), and the ongoing costs also relatively low (e.g., no more third-party service fees). It drastically lowers the cost of transmitting funds and lowers the barrier to having a bank account, obtaining credit, and investing. It could even support micropayment channels, matching minute-by-minute service usage with minute-by-minute payment.

The Ledger of Things enables "distributed capitalism," not just redistributed capitalism. Far from a free-for-all, these markets can be shaped according to our values—as individuals, companies, and societies—and these values coded into the blockchain, such as incentives to use renewable energy, use resources from our closest neighbors first, honor price commitments, and protect privacy. In short, the Ledger of Everything on top of the IoT animates and personalizes the physical world even as we share more. As IBM stated, "At a macroeconomic level, we are all winners in the IoT future, even though different industries will experience a mix of different effects."[27] According to the McKinsey Global Institute, the economic value of the IoT has, if anything, been underestimated; the economic impact—including consumer surplus—could be as much as $11.1 trillion per year in 2025 for IoT applications.[28] That's a 10 percent lift on current global GDP of well over $100 trillion; that's huge!

Networked intelligence, a phrase coined in *The Digital Economy,* referred to how the network would be smarter than its smartest node in one domain after another. As we have explained, the first generation of the Internet dropped transaction costs somewhat. We have faster supply chains, new approaches to marketing, and peer-to-peer collaborations like Linux and Wikipedia on a massive scale, with many innovative new business models. Blockchain technology will accelerate this process. As the Internet of Things takes hold, these trends will go into hyperdrive.

THE FUTURE: FROM UBER TO SUBER

We've covered a lot of ground in this chapter. Now let's pull all the strands of innovation together in just one scenario.

Consider service aggregators like Uber and Lyft. Uber is an app-based ride-sharing network of drivers who are willing to give other people a lift for a fee. To use Uber, you download the Uber app, create an account, and provide Uber with your credit card information. When you use the app to request a car, it asks you to select the type of car you want and marks your location on a map. The app will keep you posted on the availability and whereabouts of your prospective driver. At the end of the ride, Uber automatically charges your credit card. If you don't want to give the default tip, then you need to change your billing settings on Uber's Web site.[29] Uber Technologies, Inc., the company behind the development and operation of the Uber app, retains a share of the price paid for every ride.

It sounds great, particularly in cities with a small taxi fleet. But Uber's services come with a number of problems and red flags. Driver accounts have been hacked, rides are subject to surge pricing, and passengers have been subject to reckless driving and sexual harassment or assault.[30] Uber is also tracking users' every move, releasing some of this information to city officials for traffic studies. To top it all off, drivers create considerable value but they get to keep only part of it.

Now let's imagine the Uber experience if it were a distributed application on the blockchain. Mike Hearn, a former Google employee who quit his job to work full time on bitcoin, laid out this alternative universe based on bitcoin technology at the 2013 Turing Festival.[31] Hearn called this network "TradeNet" and described how, with the help of bitcoin, people could begin to rely on driverless vehicles.

It works like this. Most people don't own cars, but rather share vehicles in a commons. In Chicago, Melissa requests a car through SUber (think blockchain Super Uber). All the available vehicles start automatically posting offers, which Melissa's node ranks and presents to her based on her selection criteria. Melissa factors in how much she's willing to pay for faster routes (e.g., higher-priced toll lanes).

Meanwhile John, unlike most users, is a SUber vehicle owner and as his self-driving car is taking him to work, it identifies all the parking options, both public and privately owned, selects a space, and reserves and pays for it through an autonomous parking marketplace. Because John's predetermined parameters always include seeking the cheapest available spot within a ten-minute walk of his destination, he almost always goes with his car's first choice. The underlying parking database that supports the parking also contains information on parking rules for specific streets on different days and at different times of day, whether or not the parking space is covered or in the open, or whether the owner of the space has established a minimum price. All this runs on a distributed peer-to-peer platform—connecting multiple apps—so no centralized company is mediating the orders or taking part of the fee. There is no surge pricing and no unexpected fees.

What is striking about this proposed model is not the driverless vehicles, because self-driving cars will be commonplace—probably sooner rather than later. Rather, the cars could be fully autonomous agents that earn their own fares, pay for their own fuel and repair, get their own auto insurance, negotiate liability in collisions, and operate ("drive") without outside human control, except when they need to take some entity—maybe a human being—to court.

As a condition of operating, SUber administrators could program the vehicles' protocols into the blockchain to obey all traffic rules, take the most direct, fastest, or least expensive route, and honor their bids. The drivers' initial entry and registration into the SUber system could require vehicles to

register necessary documentation including ownership, safety inspections, and insurance, and the system would permanently log these records to ensure reinspection or insurance and permit renewals as required. Sensors could monitor the overall "health" of the vehicle and signal necessary repairs, make the appointment at the appropriate repair shop, and preorder any necessary parts. Because the vehicles are driverless, they're not subject to sarcasm, cronyism, sexism, racism, or other forms of human discrimination or corruption. Plus, they won't try to push their politics or line the dashboard with incense. All of this happens behind the scenes, between objects, and powered by an autonomous application. The drivers have created a blockchain cooperative as described in the previous chapter and they receive nearly all the wealth they create. The users—Melissa and John—experience only the convenience, with none of the hassle. What's not to love?

Where the Internet reduced the costs of search and coordination, a digital currency like bitcoin on the blockchain will enable us to cut the costs of bargaining, contracting, policing, and enforcing these contracts. We'll be able to negotiate the best deal and get the promised delivery from any other entity that will accept bitcoin, including a driverless taxi. How will the Ubers of the world compete?

But the scenario doesn't stop there. Intelligence designed into the city's infrastructure will move traffic along (variable lane direction, variable pricing, automated traffic signal management based on traffic flow), further reducing wasted energy and costs. The blockchain could support safety controls, both on the vehicles (driver and driverless) and/or on the infrastructure, such as proximity warnings and automated braking, as well as antitheft or prevention of unqualified or inebriated drivers from taking the wheel. In addition, cities will use the sensors to help manage the transportation infrastructure, including asset management of infrastructure and fleets, monitoring rail line and pavement conditions, generating maintenance plans and budgets, and dispatching repair crews when necessary.

What's truly powerful, the systems work together—intelligent vehicles operating on an intelligent infrastructure. While there will still be business for drivers of shared vehicles, autonomous vehicles will be able to operate safely on city streets with their built-in navigation and safety systems, often interacting with the intelligent infrastructure to find and pay for an accelerated lane, or parking, or to search for and find a preferred route. The ready availability, affordability, and reliability of the autonomous vehicles will significantly reduce the number of private vehicles that, like the commercial real estate example above, are often just parked waiting and unused.

And it won't just be technology or car companies that will make this happen. While all of this could, in theory, be developed, owned, operated, and managed by a single civic transportation authority, that is likely not to be the path forward. SUber is more likely to evolve and innovate as an open and shared transportation platform, with various applications developed and introduced by local entrepreneurs, community groups, government, and others in either a profit-making (through revenue earned on a fleet of driverless vans), shared co-op (a neighborhood group invests in ten vehicles to be reserved and shared using the SUber app), public service (maintaining and operating a train or express buses on high-demand routes), or social enterprise (not-for-profits investing in SUber "points," which their clients can access when they need transportation).

This may emerge first in jurisdictions with relatively advanced infrastructure, already separate transportation corridors (rail, road, bike, pedestrian), significant transportation issues (traffic congestion), and a population with a long tradition of obeying traffic rules. It may also begin in "greenfield" city developments in cooperation with technology companies and car companies looking for test beds for their applications. Any scenario involving driverless vehicles would be less successful, even highly dangerous, when other road users cannot be isolated (on separate corridors), or predicted (animals on the road), or controlled (distracted pedestrians).

The SUber scenario is increasingly feasible. Such applications will likely emerge in the next few years and come to solve our transportation needs over the long term. Already today, local taxi and limousine commissions are battling Uber in many cities. City governments are struggling to balance consumer desire for affordable options with public safety and taxi licensing, even as the new models are seemingly inevitable. Why not look where the transportation sector is going and design solutions that best meet the city's needs, as Chicago has done in our hypothetical SUber scenario?

HACKING YOUR FUTURE FOR A WORLD OF SMART THINGS

We've seen throughout this chapter some mind-boggling opportunities in virtually all aspects of our lives, including—perhaps especially—many areas barely touched by the first wave of the digital revolution. At the same time, these opportunities threaten existing businesses and ways of doing business.

Key Issues: What should you as a manager be doing on both sides of this equation—to realize new opportunities, while minimizing threats? Whether you're a manager in the public, private, or social sector, do you have un- or underutilized physical assets that can be tapped for greater value? Are you realizing the greatest possible efficiencies and opportunities to develop products and technologies for the IoT itself? Are new entrants into this economy taking your customers and reducing your revenues through innovative new app-based business models that you should be installing first?

New Value: What are your physical assets and how can you enhance them to deliver greater value to your organization or community? Do you have physical spaces, machines, inventory, or other assets that you could tag, monitor, and animate as part of an autonomous network where you establish the operating parameters to drive out costs or add value? Could you embed, upgrade, and program sensors as part of a larger network for greater functionality and value? Could you glean new information from an IoT network to improve your planning and analysis for the future?

New Business Models: What opportunities exist for new products and services based on the new functionality and data you could gather through your network? Could your information and assets earn revenue because of their value to others, for example, renting out that expensive piece of equipment when you're not using it? Thinking about the value of information is not new (remember Sabre and American Airlines?), but still overlooked.

Opportunities: Could you link your network up with others for even greater value, perhaps as part of an end-to-end supply chain or distribution and sales channel? As an industry, are there shared processes and functions that could be automated by utilizing the blockchain? Are you enabling this interoperability by using technology built on open standards and vetted through international collaboration?

Threats: What lines of business will new entrants attack with their new IoT-based business models to serve markets that you currently serve? For example, rather than a one-time sale of a vehicle, consumer good, or piece of specialized equipment, is there ongoing value for you and your clients in a new service model built upon your ongoing connection to that equipment? Can you capitalize upon your existing expertise, resources, infrastructure, and customer loyalty to design new IoT-based business models that decrease the "space" and, therefore, the likelihood of entry of a disruptive new player?

Business Case: What are the costs and benefits of these opportunities? Where does the real value exist for your organization? Are you solving an actual business problem or need or just leading with the technology? How about developing a proof of concept with a leading client?

Strategic Plan: According to McKinsey, "executives will need to deal with three sets of challenges: organizational misalignment, technological interoperability and analytics hurdles, and heightened cybersecurity risks."[32] We add a fourth major challenge to this list—building in privacy and an incentive plan, including appropriate safeguards, from the beginning. How will IT and business functions have to adapt to the IoT? Which parts of the organization and business leaders should you involve?