Communications of the Association for Information Systems

Volume 49 Article 6

9-21-2021

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Panel Report DOI: 10.17705/1CAIS.04910 ISSN: 1529-3181

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Abstract:

The 21st century has introduced the 4th Industrial Revolution, which describes an industrial paradigm shift that alters social, economic, and political environments simultaneously. Innovative technologies such as blockchain, artificial intelligence, and advanced mobile networks power this digital revolution. These technologies provide a unique component that, when integrated, will establish a foundation to drive future innovation. In this paper, we summarize a 2019 Association for Information Systems Americas Conference on Information Systems (AMCIS) panel session where researchers who specialize in these technologies discussed new innovations and their integration. This topic has significant implications to business and academia both as these technologies will disrupt the social, economic, and political landscapes.

Keywords: 4th Industrial Revolution, Fifth Generation (5G) New Radio (NR), Blockchain, Artificial Intelligence, Machine Learning, Enabling Technology, Technological Integration.

This manuscript underwent editorial review. It was received 5/29/2020 and was with the authors for seven months for two revisions. Lauri Wessel served as Associate Editor.

1 Introduction

Throughout history, society has continually progressed and made incremental advances that result in new capabilities that benefit humanity. In three instances, these advances and societal changes proved so significant that humanity considered them an industrial revolution that caused a paradigm shift in the way we think, operate, and interact. In the 21st century, we have seen a significant growth in computing, data storage, processing, and telecommunications that make a new revolutionary change called the 4th Industrial Revolution (4IR). These changes will include not only technical but also human advancements via interactions between physical devices and augmented capabilities. Scholars have argued that accumulated and fused technological evolutions characterize the 4IR (Kodama, 2018). They have identified various technologies as significantly influencing the 4IR such as industrial robots (Pham & Ahn, 2018), the Internet of things (IoT), 5G networks (Alsuhli, 2019), artificial intelligence (AI) (Shafin et al., 2020), and blockchain (Chuen & Lee, 2017). IT infrastructure's foundation comprises computing platforms, communications networks, and data (data management and data processing), and IT applications (Byrd & Turner, 2000). Each emerging technology influences a different IT infrastructure area. Blockchain, an emerging technology, provides innovative advances in data management through decentralized public ledgers (Glaser, 2017), whereas 5G telecommunications provides faster network speeds for data transmission and network slicing technology that enable innovative services such as autonomous vehicles, drone network, wireless robotics, and more (French, Risius, & Shim, 2020). Artificial intelligence provides the processing capabilities for autonomy that many of these innovative services rely on. These advancements in IT infrastructure fuel the 4IR. While these technical advancements will have a significant transformative effect on business, numerous theoretical and societal impacts will accompany this new revolution.

As humanity has seen in previous industrial revolutions, fear exists that advancements in technology will render human workers useless as technology replaces them. Technologies such as AI further instill such fears (Wilson, Daugherty, & Morini-Bianzino, 2017). However, advancements in technology such as AI will also create new jobs unlike the ones that currently exist, which will result in new ways of thinking and a shift in human-computer interactions (Wilson et al., 2017). From a behavioral research perspective, we will need to revisit old theories based on this paradigm shift and to develop new theories to address phenomenon we have not yet discovered. Design science's and behavioral science's theoretical underpinnings will intertwine and create new opportunities for research. To understand 4IR's theoretical impacts, we will first need to explore the technical advances that will impact business and society. Recent research has evaluated various technologies that fuel the 4IR such as blockchain, artificial intelligence, and advanced mobile networks. However, it is the fusion of technologies that provides the overall infrastructure that creates the paradigm shift identified as the 4th Industrial Revolution (Kodama, 2018). Previous research has explored the integration among technology pairs such as artificial intelligence and blockchain (Gill et al., 2019; Mashamba-Thompson & Crayton, 2020; Singh, Sharma, Yoon, Shojafar, Cho, 2020) or artificial intelligence and 5G services (Al-Turjman, Lemayian, Alturjman, & Mostarda, 2019; Alsuhli, 2019). However, it is the integration of all these technologies that will result in the 4th Industrial Revolution and decisively shape the 21st century. In this paper, we report on a panel session at the 2019 Americas Conference on Information Systems (AMCIS) where researchers who specialize in these technologies discussed new innovations, their integration, and how that integration will disrupt business and society to create revolutionary changes that will transform the future.

1.1 The Panel

In congruence with the conference's theme "New Frontiers in Digital Convergence", we held a panel called "The 4th Industrial Revolution Powered by the Integration of 5G, AI, and Blockchain" that involved leading experts in their respective areas who introduced and discussed new frontiers in emerging technologies and their integration as they shape the future of industry and society alike. While researchers have discussed concepts such as artificial intelligence and machine learning since the 1950s, advances in processing and storage technology, advances in data management (i.e., big data), and larger data quantities have provided the foundation for its real-life applications in almost all fields. Emerging technologies such as blockchain and fifth generation (5G) provide the foundation for future innovations to expand and integrate networks and safely share data across all industries. These three technologies offer tremendous opportunities that warrant exploration and guidance as we move towards the future. The panel addressed these topics through two discussion rounds. In the first discussion round, the experts introduced the emerging technologies along with opportunities and concerns around their integration. In the second round, the experts provided their insights into these technologies' implications for academia and made recommendations for research.

1.2 Organization

We organize the panel report according to the panel discussion's format. Thus, in Section 2, we describe the panel's theme and overview the 4IR. In Sections 3, 4, and 5, we highlight each innovation (i.e., artificial intelligence, blockchain, 5G new radio (NR)) that the panel covered. In Section 6, we expand on the three previous sections and highlight the future of technological integration and impacts that such integration will have. In Section 7, we describe research implications and recommendations. Finally, in Section 8, we conclude the paper.

2 4th Industrial Revolution

The phrase "industrial revolution" describes an industrial paradigm shift that alters social, economic, and political environments simultaneously. Substantial advancements in infrastructure in which society and business environments operate accompany these changes. Technological advancements have arrived at an apex where a new revolution will soon unfold and pave the way for the future. Three independent technology evolutions (i.e., data exchanges with blockchain, network speeds with 5G, and data processing with artificial intelligence (AI)) provide the converging factors that stimulate this change and provide a new technological foundation for the 4th Industrial Revolution.

Integrated technology that axiomatically transforms organizational and societal actions and behaviors characterizes the 4IR (Schwab, 2017). 5G (which increases mobile networks' capabilities), blockchain technology (which has begun to redefine the way we transact), and AI (which supports cognitive automation) in combination will drive this revolution. Together, these technologies will result in ubiquitous high-speed distributed networks and hyper-connected webs that contain devices and people that intelligently share information and knowledge in a secured and trusted manner. Figure 1 outlines the evolutionary changes that have impacted industry and society throughout our history.

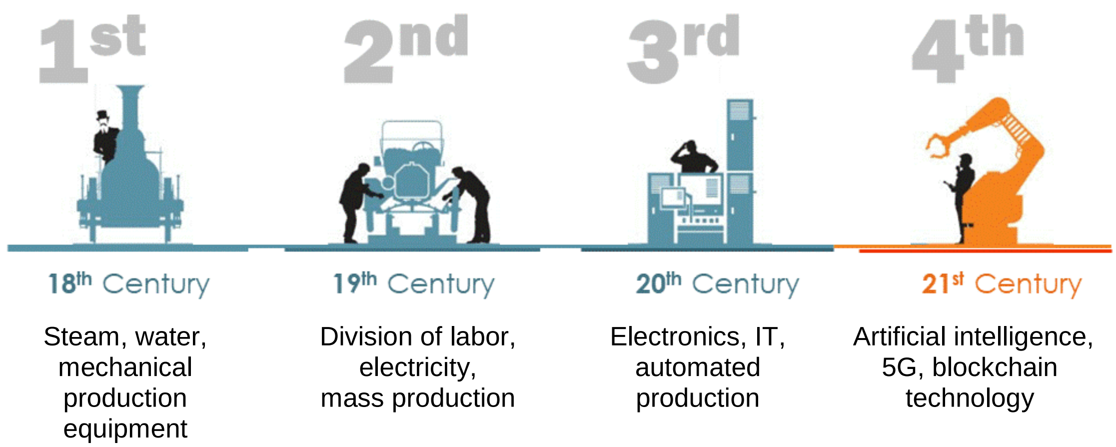

Figure 1. Industry's Evolution through Four Industrial Revolutions

These technologies will have significant impacts on businesses as they replace or transform job roles. Accordingly, employee skills will need to evolve or change and customer interactions will expand. New job categories will come into existence such as trainers, explainers, and sustainers (Wilson et al., 2017). It will take human expertise to train these new systems to perform highly sophisticated tasks with empathy. People will need to interact with AI in order to continuously help it learn; otherwise, programmed devices such as Alexa and Siri will default to canned responses to customer demands. The explainer category will serve as an intermediary between technology experts and business leaders to provide clarity on technology and its outcomes. The sustainer category will ensure that technologies operate in their intended manner. Machine learning will need to continually analyze data, which could have ethical implications due to data bias. Human experts will need to monitor the outcomes that AI produces to avert any negative consequences that could result due to data bias or other issues that may arise. The 4IR will also bring societal changes as it affects how people and businesses interact with one another. To fully understand these effects, we must better understand the technologies that fuel this paradigm shift.

No single technology will result in this revolutionary change (Kodama, 2018). AI and machine learning provide automation capabilities, which may not be revolutionary in themselves. Researchers have discussed automation using AI technology since the 1950s with theoretical machine learning models. However, recent advancements in technology have provided the foundation for these theoretical models to become realizable actions. Thanks to big data and various new technologies that have increased how much data organizations can capture and produce, AI and machine learning can start living up to their expectations and potential. While 5G provides communication capabilities between humans, objects, and between humans and objects located anywhere in the world, the data generated through this interaction will further fuel big data's growth and AI's capabilities. Blockchain provides the foundation to integrate many different technologies and services and, thus, to create opportunities to link previously independently applications. IoT will become the product of this movement and provide services to end users that take advantage of the benefits that AI, 5G, and blockchain technologies provide.

3 Artificial Intelligence and Machine Learning

Researchers have focused on how one can use computers to carry out intelligent tasks since the 1940s. Indeed, John McCarthy coined the term "artificial intelligence" in 1955 (Wang, 2019). Researchers have often debated AI from two ideologies that differentiate between using neural thinking or logical rules to achieve intelligent behavior (Aleksander, 2004). This debate operates on various dimensions, such as structure AI, behavior AI, capability AI, function AI, and principle AI (Wang, 2019). The term AI has arguably become an umbrella for many different technology categories that people have developed to identify intelligence and intelligent behavior in some form ranging from machine learning to conscious robotics. In its early days, AI relied on searches to determine appropriate actions but has since progressed to execute logical operations. By implementing human know-how into programming logic, businesses can create practical ways to use AI that they often categorize as expert systems or knowledge-based systems (Aleksander, 2004). Classical views of AI, often referred to as knowledge-based AI, commonly implemented decision trees and model-fitting techniques such as regression. In contrast, artificial neural networks (i.e., behavior-based AI) provide capabilities to extract nonlinear relations and identify interactions among predictor variables (Anandarajan, 2002). Researchers have evaluated neural network structures using two topologies for classifying behavior: 1) the multilayer perception network topology that uses feed-forward connections and 2) simple recurrent network topology that uses feedback loops (Anandarajan, 2002). While some use AI to predict human behaviors, others seek the ability to imitate social behaviors.

3.1 Machine Learning

Machine learning and its many variations constitute one of the most talked about AI technologies today (Benaich & Hogarth, 2019). While the AI concept lacks clarity, machine learning more specifically refers to "an application of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed" (Expert System, 2020). Machine learning uses statistical techniques to "learn" from data—a process called training a model using a learning algorithm that progressively improves model performance on a specific task. The availability of massive and increasing amounts of data has contributed to improved learning algorithms that can now automatically learn from data and, most importantly, from its operating environment. This learning has the potential to create a situation in which machines acquire an increasing amount of knowledge such that humans can no longer control them. One branch of machine learning known as reinforcement learning uses goal-oriented learning behavior where algorithms learn an action. It uses trial and error simulating a game environment with rewards and penalties to achieve a final goal. Deep learning, on the other hand, mimics neuron layers in the brain to automatically learn how to recognize intricate patterns in data. Many people and organizations have successfully used this technology to train computers to recognize various images and enable applications such as autonomous vehicles and diagnosing complex diseases like cancer.

Another machine learning branch called transfer learning focuses on storing knowledge gained in one problem and applying it to a different or related problem. To do so, a trained model needs to retain knowledge and apply it with new data specific to a new task. Transfer learning posits that a trained machine learning model can reapply (or "transfer") the knowledge it acquires during the training process for a new task. Reusing previously acquired knowledge reduces how much data a model needs to learn a new task. A model pre-trained on many different problems will internalize more knowledge about the world and, therefore, represents a crucial step towards generalizing AI. For example, Google first trained its InceptionV3 network on ImageNet with a large number of images and then retrained it with 129,450 clinical images that depicted 2,032 different skin diseases (Benaich & Hogarth, 2018). It learned how to classify images based on pixel inputs and disease labels only. The model outperformed 21 Stanford dermatologists in identifying cancer. Computer vision technology can quickly describe visual scenes by learning to detect objects ("nouns") to describe the scenes. Truly understanding a scene requires one to understand actions ("verbs") and common sense. One uses deep learning algorithms and videos with labeled actions and objects to train models. One can use crowdsourcing approaches to generate a large set of labeled videos that one needs to train the algorithms.

One could further enhance these capabilities by combining human expertise with machine learning to augment human's capabilities rather than replacing them. For example, doctors provide not only medical services for patients but also valuable human interactions that require compassion, empathy, and understanding. By using machine learning's capabilities, physicians can more successfully diagnose various diseases and, thus, better treat and care for patients. To ensure machine learning has such capability, one would need to train not only the algorithms but also people to use these technologies and understand how they interact with systems. Such training will require significant investments from companies to achieve the desired results but also research effort to understand related behaviors to achieve success.

The above trends and applications drive significant business investment into AI technologies. Figure 2 shows the results from the 2017 PWC survey on what technologies major corporations have invested in. Furthermore, a recent Accenture survey reveals that 2019 trends have moved toward distributed ledger technology (DLT), artificial intelligence (AI), extended reality (XR), and quantum computing (DARQ) (Daugherty & Carrel-Billiard, 2019).

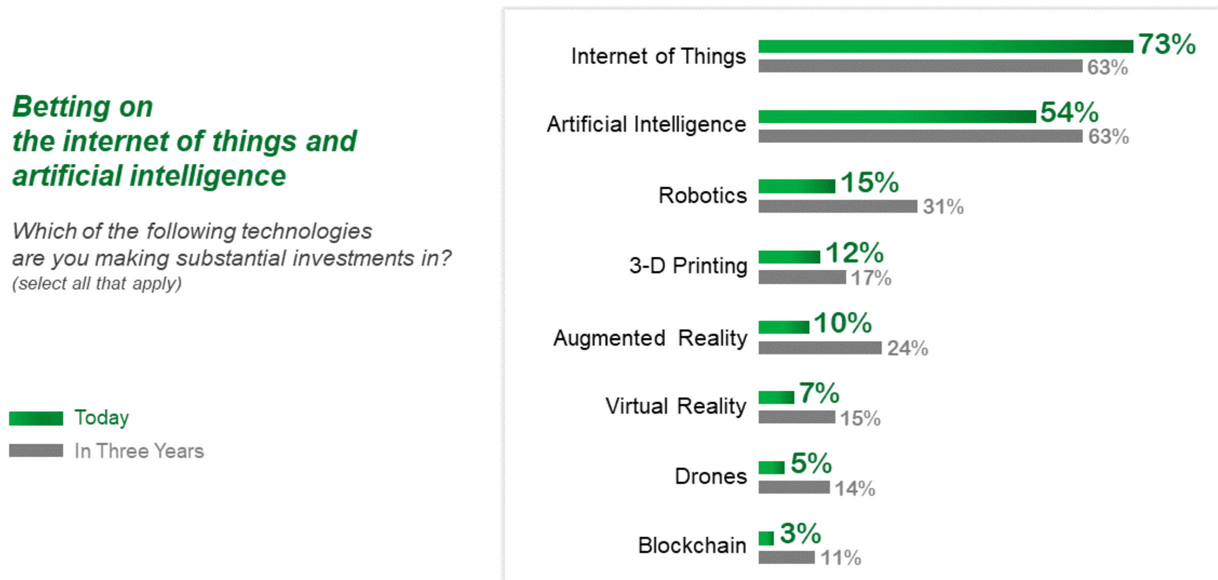

Figure 2. Technologies that Companies have Invested in (PwC, 2017)

3.2 AI and Machine Learning Applications

AI-based applications that researchers have developed in various disciplines provide insights into the broad and deep impacts that AI may have. In the new drug development area, researchers have begun to teach machine learning models to learn rules about designing drugs (e.g., the structure of therapeutic molecules and the stepwise process of efficiently synthesizing them). One can then use these models to improve existing drugs, generate entirely novel compounds, or new drug combinations. In the government, area China continues to roll out CCTV surveillance software based on computer vision. China had 170 million CCTV cameras in late 2017 (Benaich & Hogarth, 2018). This network will grow to 400 million cameras in three years. Face- and body-synthesis technologies now allow one to film an on-set video once and generate the same video in different languages by matching the face to spoken word. The next step involves generating entire bodies from head to toe. Realistic speech synthesis comes after image and video manipulation. Researchers have been working on using neural networks to decode thoughts from brain waves. Researchers at Columbia University used invasive electro cartography to measure neural activity in five patients undergoing treatment for epilepsy while listening to continuous speech sounds (Benaich & Hogarth, 2019). Researchers reconstructed speech from neural activity in the auditory cortex. The system achieved 75 percent accuracy when tested on single digits played via a vocoder. The deep learning method improved speech's intelligibility by 65 percent over the baseline linear regression method. The research indicates the potential for brain-computer interfaces to restore communication for paralyzed patients. In the cybersecurity area, organizations have used machine learning algorithms to detect insider threats by using large amounts of data on employee behavior, which reduces the time to flag potential malicious intent. They have also used supervised learning to identify malicious activity in their network based on data from past attacks. Organizations use unsupervised learning to automatically learn normal and abnormal activity in a network on an ongoing basis. Tremendous growth and increasing competition in electronic commerce have resulted in smaller order size for item picking in warehouses and increasing customer expectations around fulfillment speeds. Organizations lack warehouse space and labor, which drives them to use robotics more. Retailers have also reacted to Amazon's investment in this area following its Kiva acquisition.

Semiconductor (or "chip" for short) performance drives behind progress in AI research and applications. Graphics processing units (GPUs) constitute today's workhorse chip for AI models. What took six days to process in 2010 can be done on GPU today in 18 minutes. GPUs offer immense computational parallelism over central processing units (CPUs), which results in faster training and model iteration. The positive feedback loop that Figure 3 shows also represents another major trend that has driven AI's competitiveness. GPUs' lower costs and higher performance, extremely low storage costs, and data's tremendous available have resulted in bigger models that provide better performance. In turn, these benefits have resulted in organizations collecting more data through various means, which has driven significantly more investment into AI technologies worldwide.

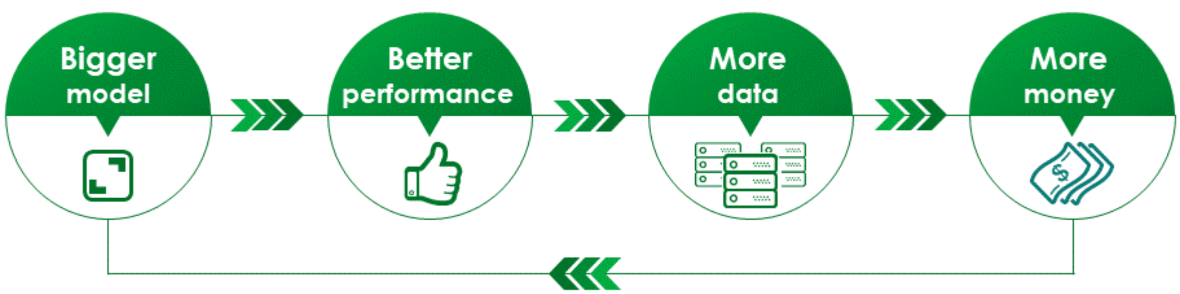

Figure 3. Positive Feedback Loop

4 Blockchain as an Enabling Technology

Blockchain technology has the potential to provide the infrastructure for digital, biological, and physical elements to converge in the 4IR (Schwab, 2017). Blockchain technologies enable one to establish an "Internet of value". While the Internet originally allowed people to share documents, blockchain technologies enable people to exchange digital goods with value associated to them in a trusted manner without traditional intermediaries (Tapscott & Tapscott, 2017). For example, individual digital assets (e.g., a picture, a document, or a music file) can have immediate monetary value when one can uniquely identify, trace, and trade them using blockchain. By associating digital goods with tradable value, blockchain technologies can enable the Internet of value, which will create new markets as peer-to-peer transactions maintain autonomy rather than requiring third party intermediaries such as eBay or Amazon. Blockchain technologies have the potential to be an essential component to the future infrastructure for the 4th Industrial Revolution and industry 4.0.

AI constitutes another related technological innovation that will advance the 4IR. With their potential to swiftly analyze different types and large amounts of data, AI algorithms can facilitate and automate complex decision-making processes (Schwab, 2017). As organizations continue to invest more into AI and blockchain technologies, the question arises how their integration can provide value for the socio-technical transformation we have begun to experience.

4.1 Blockchain Empowering AI

Considering that blockchain constitutes a database technology (Glaser, 2017) and AI provides unprecedented analytical capacities, one may naturally ask how blockchain can support AI analyses (see Figure 4). We understand blockchain broadly as a distributed ledger technology that stores transactional data in cryptographically linked blocks, which establish a single source of truth through a decentralized consensus mechanism (Risius & Spohrer, 2017). Therefore, the obvious response to that question would be by providing access to validated data. To properly address how blockchain can support AI, however, the more challenging follow-up question concerns what kind of data one can provide to AI algorithms through blockchain and what purpose blockchain can serve.

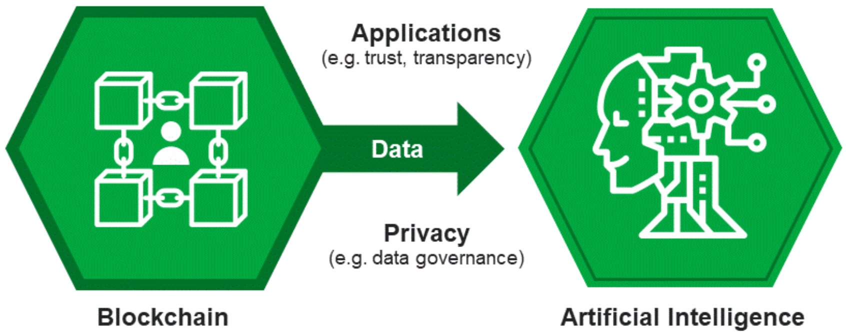

Figure 4. Blockchain Supporting AI

The answer to what kind of data blockchain can provide depends on the purpose for which one deploys the technology. Researchers often refer to blockchain as "innovative technology in search of use cases" (Glaser, 2017, p. 1543). Consulting companies do not grow tired of conceptualizing general application fields and industries (Carson, Romanelli, Walsh, & Zhumaev, 2019). Simultaneously, we see various established companies and start-up projects release many news releases on prototypes, while live blockchain applications in the real world remain scarce. Recently, Pedersen, Risius, and Beck (2019) published a ten-step decision path that helps to determine whether something constitutes a viable blockchain use case. Generally, we need to acknowledge that blockchain represents a poor substitute for existent databases due to its capacity, scalability, and limitations. Thus, we assume that blockchain's actual socio-economically disruptive potential lies in its capability to establish an infrastructure and environment for novel applications. In essence, these applications can provide additional business value whenever the involved parties have a trust issue or at least conflicting interests that, for whatever reason (e.g., unreliability, high costs, poor availability), they cannot solve through a trusted third party (Pedersen et al., 2019). If we do not have a prevalent trust issue, some would argue that implementing blockchain makes only sense for audit purposes (Glaser, 2017). Blockchain's potential to make trusted data transparently available to participating nodes means that AI algorithms have high-quality data to draw on. We would consider applications in supply chain management (Pedersen et al., 2019) and financial services (Chanson, Gjoen, Risius, & Wortmann, 2018a; Chanson, Risius, & Wortmann, 2018b; Nofer, Gomber, Hinz, & Schiereck, 2017) as the most viable candidates for blockchain application in the near future.

In addition to this reliable and transparent data from potential application fields, blockchain supports AI in another way by offering the potential to preserve data privacy. While we acknowledge the potential privacy threats to blockchain-based systems (Risius & Spohrer, 2017), the technology itself has great potential to safeguard individuals' privacy as the ever-increasing regulatory know-your-customer (KYC) struggles and efforts prominently illustrate (Hochstein, De, & Baydakova, 2019). Enigma constitutes one of the most noticeable blockchain-related systems to preserve data privacy (Zyskind, Nathhan, & Pentland, 2015). Enigma enables (pseudo) anonymous users to store personal data off chain and control a service's access to their data. Thereby, users own and manage their data without having to trust a third party. According to legislators such as the European Commission (2018), ethical and trustworthy AI systems need to adhere to seven key requirements, and one such requirement concerns preserving data privacy and data governance. Thus, blockchain could help establish AI algorithms' trustworthiness and applicability by preserving user data privacy.

In sum, we would argue that blockchain technologies support AI via two general means. First, blockchain can make more data readily available for AI algorithms to analyze. The specific kind of data it can provide will depend on the actual blockchain use case. Second, blockchain can support AI through protecting data privacy, which will enable AI to fulfill the ethical requirements that, for example, the European Union has put forth. As such, AI can support AI's proliferation and adoption. Currently, we already see certain AI initiatives that draw on blockchain data. Projects such as Google's Deep Mind, Neuromation, and Longenesis focus on using AI with blockchain-based healthcare data. MindAI and SingularityNet, AI marketplaces that blockchain technology hosts, establish an incentive scheme that rewards users who decide to provide personal data to AI algorithms (Magas, 2019).

4.2 AI Empowering Blockchain

Interestingly, much discussion around integrating blockchain and AI to power the 4IR revolve around the data that blockchain can provide to AI algorithms. We believe that the reciprocal effect that AI has on blockchain can be just as relevant in this context (see Figure 5). Recently, smart contracts—externally initiated blockchain-based algorithms that automatically execute a transaction once the specified conditions are met (Szabo, 1997)—and decentralized applications (DApps)— blockchain-based programs that comprise one or more smart contracts—have emerged as key factors that will drive blockchain's disruptive potential.

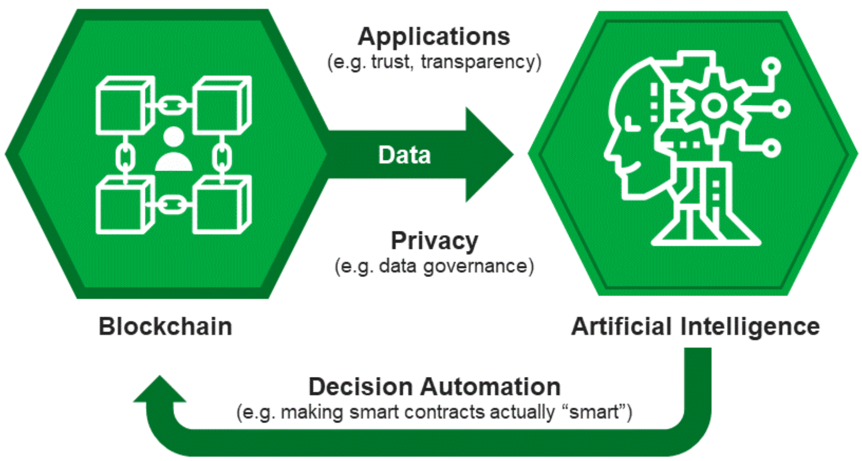

Figure 5. AI Supporting Blockchain

Since one needs to externally initiate smart contracts (Xu et al., 2017), they do not fulfill the requirements to constitute a "smart" application, which the 4IR requires (Silverio-Fernández, Renukappa, & Suresh, 2018). AI might be able to make smart contracts "smart" in the sense that they can automatically initiate. AI algorithms can swiftly integrate larger and more diverse data to determine whether they should execute a transaction or not. It does not seem feasible to implement the same complexity into smart contracts' initiating conditions.

To illustrate this idea, consider the following: people use a smart contract to manage their sports bets. To reduce their risk, they apply an AI algorithm that analyzes various team statistics to determine the probability that they will win. Whenever the AI algorithm predicts a winning probability (e.g., over 80% for a team), they would like to place a bet on that team, and the smart contract automatically sends money to bet on the respective team's win (HackerNoon, 2018). AI algorithms could enable this type of autonomous execution based on complex initiating conditions. In a fully digital economy that comprehensively relied on blockchain technologies, this example could include all sorts of transactions such as financial trading, energy acquisition, or food purchases. Cortes constitutes one project that integrates AI into smart contracts. Cortex blockchain intends to implement a machine-learning platform that allows users to post tasks on the platform or call smart contracts (Chen, Wang, Yan, & Tian, 2019).

5 5G NR and Technological Deployment

No cellular technology in any prior generation has had the potential to drive economic growth to the extent that 5G technology promises. Industry sources have reported 5G to have over 100 times faster speeds than 4G LTE currently offers (3GPP, 2020). With significant increases in speed and low latencies, 5G services will have the capability to meet connectivity requirements for high reliability and low latency services such as extended reality (XR), autonomous vehicles, drone network, smart agriculture, smart cities, mobile diagnostics, wireless robotics, and numerous use cases (French et al., 2020).

A radio access network (RAN) constitutes a part of a mobile telecommunication system. As Figure 6 shows, the RAN resides between user equipment (UE) and the core network. 4G LTE has demonstrated that multi-carrier OFDM is superior when compared to single carrier modulation and throughput (GSMA, 2018; Smee, 2018). 5G wireless network slicing also supports various other services such as enhanced mobile broadband (eMBB), Ultra-reliable low-latency communication (URLLC), massive Machine-type communication (mMTC). These services all have heterogeneous requirements (Shim, Sharda, French, Syler, & Patten, 2020).

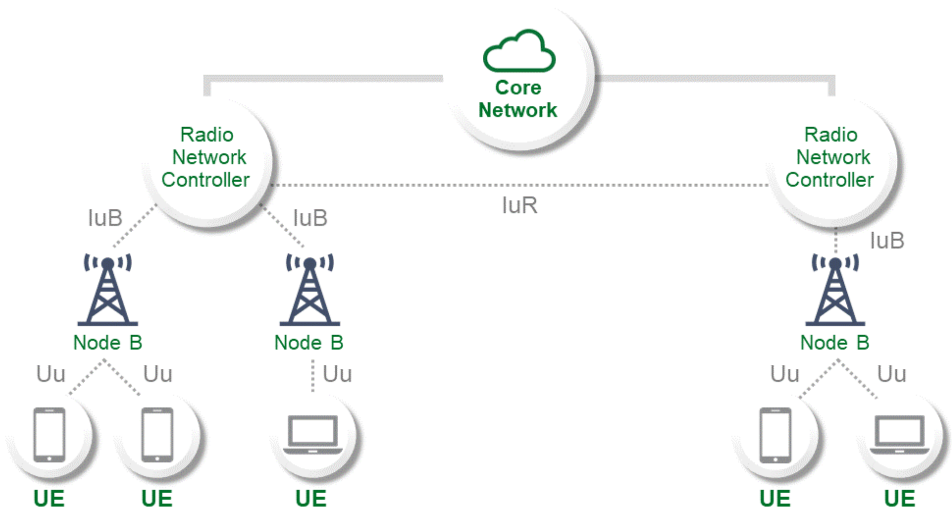

Figure 6. Radio Access Network (RAN) (Modified from SDxCentral, 2018)

Quadrature Amplitude Modulation (QAM) constitutes the means by which a carrier signal (e.g., a 4G LTE waveform) transmits data. QAM-256, initially intended for small cells, delivers benefits to carriers, vendors, and consumers at the macro level. A waveform carries as much data as possible to achieve higher data rates and increase spectral efficiency. Among its more innovative aspects, 5G architecture features network slicing, which allows operators to divide networks for specific customers and services. With unique requirements for optimization and network topology by various use cases, network slicing will be critical for 4IR. While faster speeds provide useful capabilities for transferring data and managing networks, network slicing will have more significant impacts on businesses and their ability to provide enhanced dedicated services. Figure 7 demonstrates network slicing and several use cases that will benefit from 5G services.

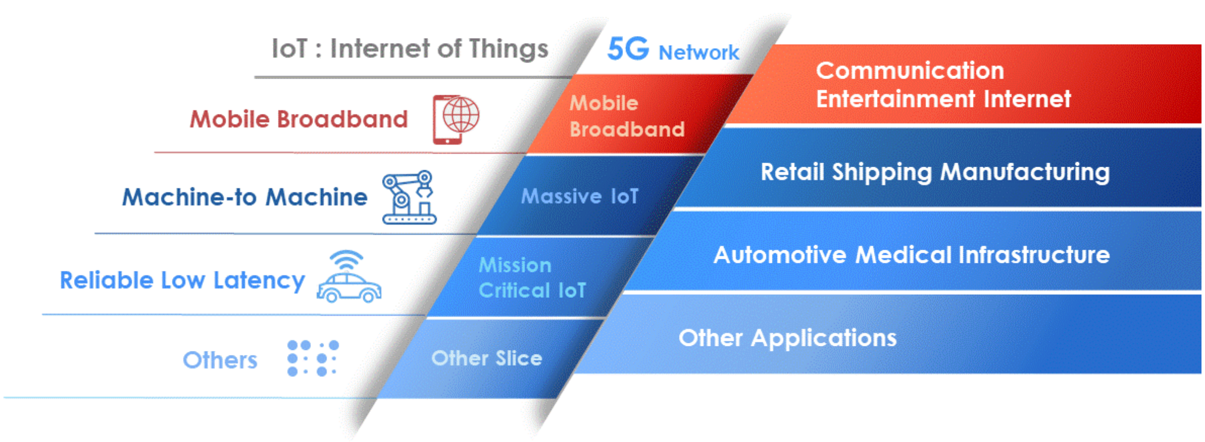

Figure 7. 5G Network Slicing (Modified from GSMA, 2018)

Figure 8 illustrates 3GPP standardization; that is, Rel-15, non-standalone (NSA) architecture, standalone (SA) architecture, Rel-16 and further development of the system via Rel-17. It also displays the pilots in 2017, proprietary networks in 2018, first commercial deployment (Phase 1) in 2019, and Phase 2 in 2020. The number of South Koreans who have subscribed to 5G cellular networks topped two million in August 2019. Currently, South Korea has secured about four million 5G subscribers (Cho, 2019).

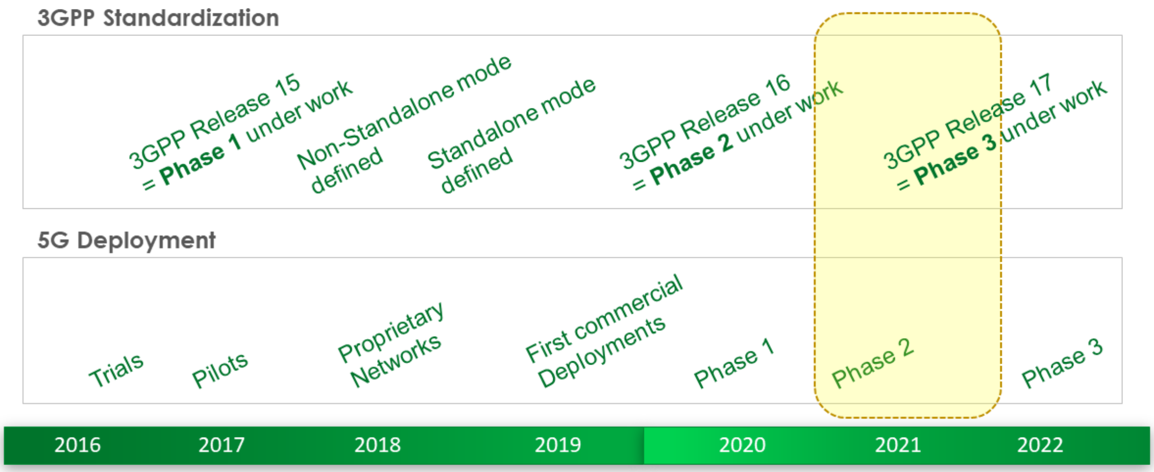

Figure 8. 3GPP Standardization and 5G Deployment (Penttinen, 2019).

Despite the opportunities that 5G creates, 5G NR faces many challenges. For instance, telecommunication companies continue to contend with spectrum cost, which includes diverse spectrum licensing (i.e., Sub-GHz, Sub-6 GHz, mmWave) and 5G telecom equipment costs that 5G deployments use. Another issue includes the fact that 5G networks also have limited range and, thus, require telecommunication companies to erect more small antennae to serve more customers. Further still, service providers can run into other issues such as local community regulations. A significant issue to date concerns Huawei's 5G telecom equipment and the potential security risks that have caused the US and many European countries to ban the company.

International Telecommunication Union (ITU) has started discussions on what mobile communications could look like in 2030 (i.e., 6G). Recently, the world's first 6G wireless summit occurred in Finland. And organizations and companies in several countries such as the United States, South Korea, and China have actively focused on creating 6G research centers and hosting consortiums for 6G (e.g., DARPA and a consortium of technology companies in the US—a collaboration between LG Electronics and Korea Advanced Institute of Science and Technology in South Korea).

6 Integrating Blockchain, 5G, and AI Technologies that Enable 4IR

In this section, we illustrate numerous areas that these technologies and their amalgamation may impact. Each technology provides a different component required to establish a foundation that will drive future innovation. Blockchain offers new solutions for data exchange through distributed ledgers. Blockchain can provide a platform for a various solutions that increase data's integrity and transparency for different industries. As numerous companies continue to implement blockchain solutions, new capabilities for data analytics become possible due to blockchain-based solutions' customer-focused nature. Customers who access services via blockchain will have transactions across all entities stored in a single location, which will increase analytics capabilities from a single entity to all entities. As 5G implementation continues to expand on a global scale, increased network speeds will create numerous opportunities for innovation. Society will be more connected than ever before with ubiquitous access to digital content and smart technology. Real-time processing via various devices that all communicate together through interactive networks will fuel this hyper-connectivity. As Figure 9 shows, blockchain and 5G technology can complement each other in various industries and ways and provide numerous solutions that advance current capabilities. For example, blockchain provides an immutable ledger with support from public key/private key cryptography that offers promising solutions to identity administration and digital asset management. Via properly validating individuals and immutable ledgers using hashing and tokenization, such technology can readily verify individuals and digital assets for authenticity and ownership. 5G technology overcomes processing and bandwidth issues that limit blockchain's potential and allow for large scale adoption on a global scale. The growth of applications on blockchain networks will continue to grow with accessibility across various user devices. In these environments, AI enters the equation and can provide the most significant benefits hitherto only theorized.

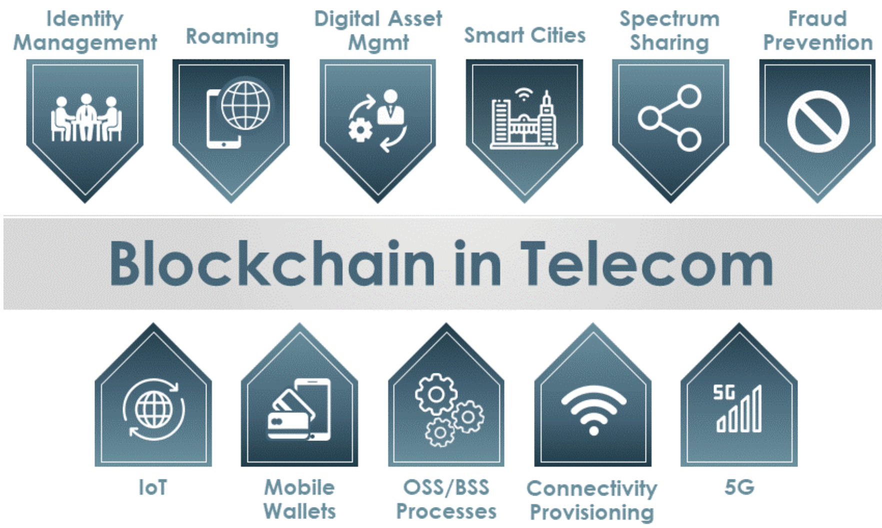

Figure 9. Blockchain in Telecom (SCALA Blockchain, 2017)

As we demonstrate above, AI concepts have existed for several decades, but we could not implement and realize their true potential due to insufficient data, processing capabilities, and affordable processing power. As data grows, machines will continue to learn, which will enable AI to reach its full potential to provide data processing and solutions that will further expand human capabilities. Figure 10 provides a multilayer framework that shows how integrating these technologies can result in new insights and value creation. At layer 0, blockchain provides a foundation that allows parties to store and exchange data in silos and, thus, enables transactions across various industries and generates data that one can use for analysis. At layer 1, the network layer, 5G provides the network speeds and network slicing that ubiquitous real-time analyses require. Such analyses further enhance machine learning's capabilities. Due to blockchain's pseudonymous nature, companies cannot just access and analyze data at will. These peer-to-peer networks allow users to autonomously control their data and to grant others access to it at their discretion. As such, users can profit from their data rather than just being a product for marketing companies who exploit user data without any benefits to who produces it. One can enable smart contracts at layer 2 to allow machine learning systems to use data across the blockchain, which incentivizes and allows users to profit directly from these transactions. At Layer 3, AI and machine learning become integrated into networks to provide additional capabilities, real-time analytics, and new opportunities for future innovations.

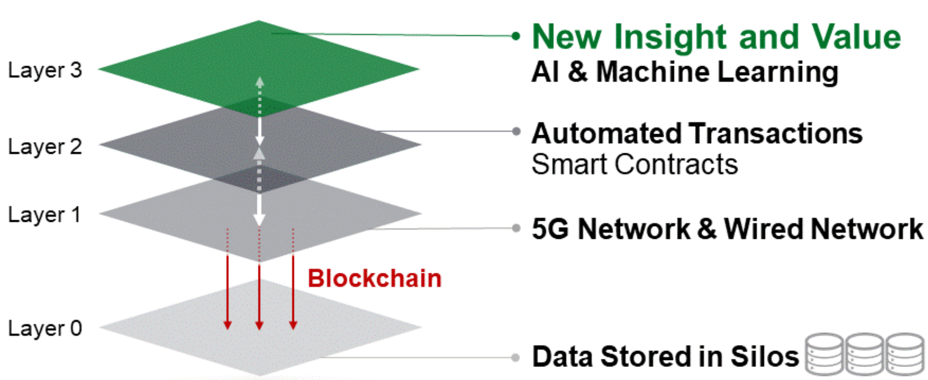

Figure 10. Blockchain and AI Integration (Modified from Houlding, 2017)

While allowing for real-time capabilities and machine learning, 5G and blockchain also provide numerous opportunities for AI to enhance innovation. In Figure 11, we compare current services that companies offer through existing networks and the expanded capabilities that they could obtain via implementing 5G services. Entertainment media have discussed and presented autonomous driving for decades, but we lack widespread practical implementations. For autonomous cars to work, numerous sensors must process and analyze data related to traffic conditions, speeds, weather, road conditions, driving directions, and more in real time. It only takes a second for conditions to change, and an autonomous vehicle must be able to react instantaneously in real time to prevent fatal outcomes. Thus, autonomous cars require high speed and reliable networks, such as 5G, to constantly connect to the network and transmit data. AI must have the capability to analyze data instantaneously to provide split second directions to the vehicle to operate safely. This and other countless examples illustrate the revolutionary change that will arrive with the 4th Industrial Revolution.

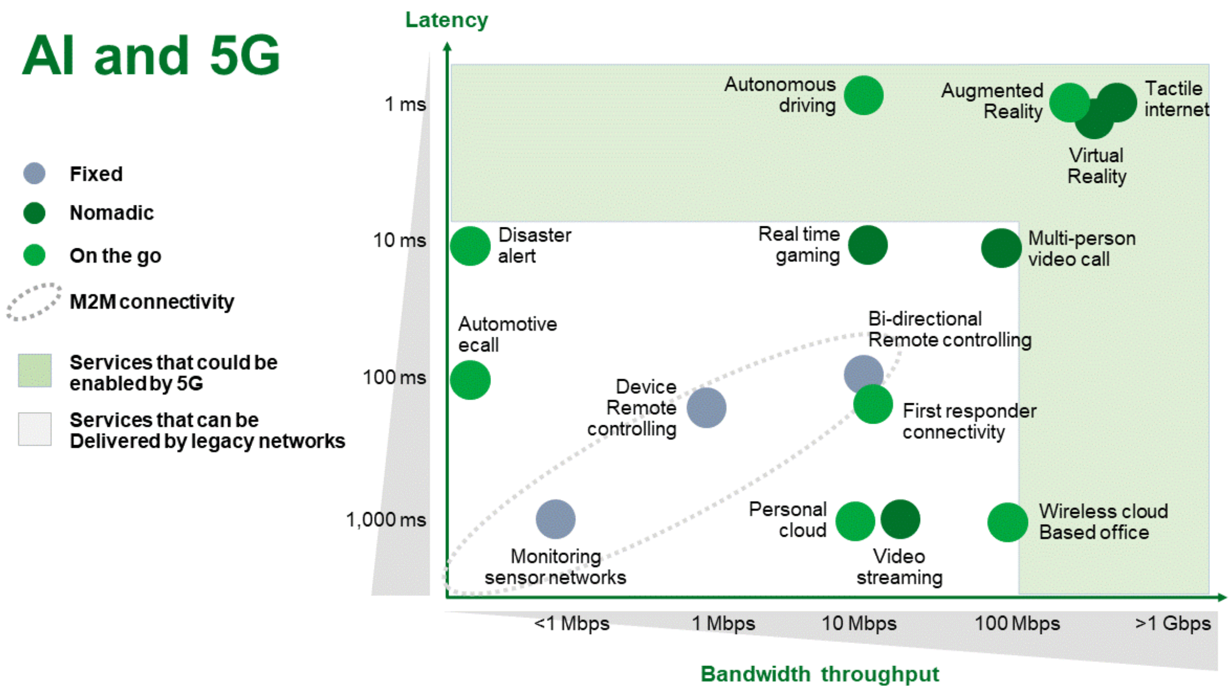

Figure 11. Artificial Intelligence and 5G (Modified from Gresset, 2017)

While autonomous cars might seem like a novel way to integrate these technologies, autonomous technology could disrupt every industry in existence. For instance, logistics companies could expand their deliveries beyond regular schedules. Just-in-time manufacturing could benefit from autonomous supply chains and manufacturing to enable an in-real-time manufacturing methodology. The tactile Internet that will result from 5G implementation will provide low latency with high availability and reliability, which will provide opportunities for real-time IoT connectivity and control. The 4th Industrial Revolution will pave the way for an autonomous digital society in which devices connect to the Internet with blockchain and peer-to-peer networks and AI continue to learn and deliver improved solutions in real time.

6.1 The Future of Blockchain and Artificial Intelligence

Blockchain and AI have a multifaceted relationship regarding cybersecurity. The most striking story that evidences the deeper relationship between AI and blockchain perhaps concerns the case where machine learning and network analyses may allow one to de-anonymize bitcoin transactions to identify individuals conducting transactions (Harlev, Sun Yin, Langenheldt, Mukkamala, & Vatrapu, 2018). Of course, using AI and blockchain in this way would contradict blockchain's features that protect privacy. Given AI's capabilities, the rather few ML use cases to attack blockchain solutions' structure may constitute little more than dents in the armor. On the positive side, researchers have suggested using AI to detect and prevent denial-of-service attacks (Somdip, 2018).

Machine learning and blockchain also have promising complementarity due to the former's insatiable need for processing power. Unless quantum computing (the fourth DARQ technology) helps general-purpose machine learning, blockchain mining and processing will continue to require more and more machine power. Graphics processing units (GPUs) may best perhaps meet this need due to their ability to handle machine learning's need for mathematical processing. Currently, when organizations need processing power to handle big data, they purchase it from cloud providers, who provide either GPUs or traditional CPUs (sometimes in the tens of thousands).

Some researchers have begun to explore the potential for blockchain to serve as the infrastructure that will allow organizations and individuals to share the processing power that sits mostly idle on personal and corporate computers. Blockchain should allow one to tie together tens of millions of computers without requiring a central provider. Because organizations and individuals massively underutilize this computing power, it would also be possible to sell it at for a much cheaper price compared to current cloud solutions. However, given the difficulty that companies face in providing a reliable cloud service even on a consistent platform and with a small army of support staff, the management challenges that such solutions face make them high-impact/low-likelihood technologies in the short term.

While one can clearly use ML and blockchain in complementary ways, we found from reviewing the popular media that such media often use blockchain and ML as little more than popular keywords. Often, in technology advancements, such as Ample, corporate social responsibility can be addressed such as a "machine-learning smart meter company aiming to reduce environmental footprint using blockchain and behavioral economics" (Tokenpost, 2019). In this case, it remains unclear whether the company requires blockchain to function. Other stories have suggested that the National Archives and Records Administration (NARA) has considered using blockchain to verify records amid the rise in deepfake videos (Heckman, 2019).

With the emergence of deep fakes and prevalence of fake news, new tools for validating and authenticating information become increasingly important. Our already limited ability to filter out fake information will only grow due to the capabilities of blockchain and ML. In short, blockchain and AI have much to offer each other, but enormous technical challenges often stand in the way. Actors who attempt to combine the two should recognize the exponential increase in complexity when adding blockchain to an already technically complex solution.

6.2 Blockchain

Blockchain can potentially support transparent and secure transactions between and among individuals, individuals and organizations, and organizations without a central authority (Beck, 2018). One can remove the constraints that need centralized authority if one can orchestrate and enforce the transaction logic without a central authority. This paradigm shift—that systems organize transactions reliably based on a protocol—conceptually resembles the autonomous vehicle. It can enable IoT devices to coordinate activities in a tamper-proof manner.

However, at present, blockchain lacks readiness for mass usage as we describe above (Dinh at el., 2018). Individuals and organizations continue to refine blockchain platforms' design and codebase, and the technology lacks any widely established applications beside cryptocurrencies (Dinh at el., 2018). Of the three central blockchain systems, Ethereum has the most maturity in terms of its codebase, user base, and developer community. Smart contracts also face portability issues due to different programming models. Compared to database systems, blockchains perform poorly at data-processing tasks that database systems currently handle. Blockchains have much learn from databases in terms of high-performance data processing needed for its wide adoption. Researchers have recently addressed the challenges in scaling blockchain by optimizing the consensus protocols. However, other performance bottlenecks besides consensus exist.

Blockchain offers non-unique features if one judges them individually. Indeed, its mechanisms largely build on well-known concepts that people have developed over years. However, in combination, the features ideally suit many applications, which justifies the intense interest that several industries have paid them (Casino, Dasaklis, & Patsakis, 2019). As blockchains become more mature, we expect their applications to penetrate many industries and domains. However, in many scenarios, companies should still use traditional databases.

Wang, Zheng, Xie, Dai, Hand Chen (2018) identified blockchain challenges as scalability, privacy leakage, and selfish mining. The blockchain technology consumes many resources, which creates scalability issues, especially with large-volume transaction systems. Furthermore, blockchain can safely protect individuals' identity if individuals use the address it generates rather than their real identity. However, research has shown that it cannot guarantee the transaction privacy since anyone can publicly access all transaction and balance values for each public key. Researchers have already begun efforts to address these issues.

7 Research Implications and Recommendations

The technologies that we describe above provide numerous research opportunities that span design science and behavioral science research paradigms. These emerging technologies individually provide numerous research opportunities but their integration presents revolutionary change and myriad research directions. Table 1 summarizes potential research topics that researchers could address in the future. The recommendations that we provide here relate to the specific topics that the experts covered in the panel.

Table 1. Potential Research Topics

Design science Blockchain's scalability Machine learning use Advancements through 5G	**Behavioral science** Social capital theory Impression management Technology use	**Societal impacts** Travel and health Marketing and sales Special needs
Ethics Ethical technology use Opportunistic behavior Information dissemination	**Privacy** Impacts on privacy Data creation Laws and regulations	**Security** Security responsibility Intellectual property Laws and regulations

While the panel discussion focused on the emerging technologies that fuel the 4IR and their impacts on business and society, research can contribute to and provide guidance in significant areas as we progress toward the future. The information systems (IS) field has predominantly focused on behavioral science, but it contains a strong design science presence that continues to grow. However, it is not a question of which approach to take—design science versus behavioral science—but rather how each paradigm can both contribute to understanding and guiding the future of research in the 4th Industrial Revolution (Larsen & Bong, 2016). From a design science perspective, researchers need to explore the many new developments in and ways to apply these technologies. With blockchain still in its infancy and various limitations such as scalability, design science research can explore new avenues and development to overcome existing barriers. Researchers should explore new ways to analyze and implement machine learning to expand on its current capabilities. They should develop and explore use cases for both blockchain and machine learning to help guide development. With 5G now available in select locations and future rollouts planned for other areas, numerous possibilities exist for AI and blockchain both to capitalize on this infrastructure and open the door for new design science research and artifacts. The IS discipline has a strong ability to lead in this area, which several innovative design science contributions in the machine learning area evidence (e.g., Li, Larsen, & Abbasi, forthcoming; Abbasi, Zhang, Zimbra, Chen, & Nunamaker, 2012). As with each previous industrial revolution, new societal effects will dramatically affect business, culture, and social interactions. We will need research to understand that impact.

From a behavioral science perspective, social capital theory and impression management will be important research areas. Social capital refers to the intangible benefits that one gains through social interactions. The 4IR provides various applications that dramatically change how social interactions take place as social networking, online communications, and virtual reality create new ways in which people interact. Researchers will need to conduct behavioral and technology use studies to understand the effects of changes in social interaction. For example, the social science literature has predominantly focused on social capital's benefits (Risius, 2014; Risius & Beck, 2014) and neglected its negative side-effects(e.g., promoting conspiracies, segregation, conformity pressures) (Portes, 2014; Portes & Landolt, 1996). Given the recent surge in societal issues related to social media (e.g., echo chambers, fake news, online extremism), the 4IR will likely exacerbate these effects. Social capital theory will help explain and predict how these phenomena will develop (e.g., generalized norms, group characteristics) (Narayan & Cassidy, 2001) if we extend it to these growing harmful implications in the 4IR context. With new means to interact comes new ways to manage the impression one gives to others. For example, in a real-life setting, people interact with a limited number of people at a time, which allows them to present themselves in the way they most desire. With virtual presence becoming more prevalent due to technological advancements, many people can view a single impression. Virtual communications also give people a sense of anonymity, which allows them to present themselves in a manner that may differ from their real-life persona. In the 4IR context, we need to carefully revisit and potentially revise impression management theory to explain how people create impressions in anonymous environments, to explain how AI-based conversational agents best engage with users (Seeger, Pfeiffer, & Heinzl, forthcoming), and to mitigate or correct AI-enabled deepfake videos' impression-distorting effects (Heckman, 2019). Understanding how people use technology to interact and manage their virtual identity will provide numerous opportunities for technology use and virtual behaviors. These technologies will have numerous societal impacts that will create opportunities for research. Advancements in technology will impact every business as 5G, AI, and blockchain become more prevalent. The travel industry will be able to provide virtual and real-life experiences that complement each other with global connectivity. Healthcare can increase its reach and range with opportunities in telemedicine, virtual treatments, and increased coverage. Marketing and sales will take advantage of the plethora of available data as ubiquitous technology will hyper-connect people. Individuals with special needs will have new opportunities. For example, healthcare professionals will be able to use a virtual environment that simulates real-life experiences to provide treatment to individuals with special needs. Understanding the impact these technologies have and how healthcare professionals can implement treatments effectively will require significant research. Considering that society's daily life will increasingly presume that individuals can competently use and embrace such technologies, researchers will need to complement technology use theory to finally inform people's paradoxical inertia to use applications, features, and technologies despite having a positive attitude towards them. To that end, researchers could introduce behavioral factors such as commitment (Risius, Baumann, & Krasnova, 2020), risk-benefit assessments (Gerber, Gerber, & Volkamer, 2018), or effort level (Dinev, McConnell, & Smith, 2015) to technology use models in the 4IR context.

While the 4IR provides numerous advantages (e.g., technological capabilities, improvements to people's lives, business benefits), we will also need to consider the serious ethical, privacy, and security issues it will raise. 5G will dramatically and further increase big data's volume, velocity, and variety. Blockchain will provide public networks with users who bear the responsibility for securing their data. AI/machine learning will provide significant advancements in data analytics and uncover new insights into human behaviors and actions. These advancements in technology provide numerous opportunities but will also open the door for individuals to opportunistically exploit data and people. Laws such as the Health Insurance Portability and Accountability Act of 1996 (HIPAA) in the United States strictly regulate hospitals; however, with blockchain, patients could ultilatemy be responsible for their own medical records' privacy and security. One could use AI to analyze patterns in data and uncover highly personal information about individuals based on purchasing habits, mobile data, geolocation information, and more. Will users need to use technology in order to exist in future societies? If so, what does that mean for their privacy? How will intellectual property be protected in a digital community and will blockchain technology help or further complicate creativity? How will new laws and government regulations impact 4IR technologies on a local, regional, and global scale? Many other questions and research opportunities exist. As we approach the 4IR, we urge researchers to ask the tough questions and lead us into the future.

8 Conclusion

The 4th Industrial Revolution has arrived, and society has begun to develop technology that will completely reshape our society and the world. Several Asian countries such as South Korea, China, and Japan lead the 5G rollout compared to other countries. South Korea was the first country to roll out 5G services in April, 2019. In the United States, 5G deployments partially adopt pre-standard technology. 5G will be transformative, but it will take time and a lot of capital investment. Considering blockchain projects remains in its early stages, we expect most projects to take design science approaches to explore the relationships between blockchain and AI to power the 4IR. First, blockchain and AI in the 4IR context have a reciprocal rather than unidirectional relationship in that blockchain can provide data to AI algorithms and AI can also support blockchain. Regarding the data that blockchain provides, we need to keep in mind the specific use case in which one might realistically deploy blockchain. Blockchain can help make trustworthy data transparent, which makes it a suitable solution for audit purposes (Glaser, 2017).

Future research will need to explore and identify viable blockchain use cases (Labazova, 2019). The decision-making process that Pedersen et al. (2019) has outlined should help researchers determine whether something constitutes a feasible blockchain use case. Furthermore, we will need to investigate how blockchain technologies can help protect individual users' data privacy to make AI algorithms ethical (e.g., Enigma) (European Commission, 2018). Lastly, AI can also support blockchain technologies by analyzing larger and more complex input patterns. AI can also automatically initiate smart contracts and, thereby, actually making smart contracts smart (e.g., Cortex) (Chen et al., 2019; Silverio-Fernández et al., 2018). Our above recommendations will help lay the foundation for more blockchain-enabled industry 4.0 applications.

Acknowledgments

We thank all the organizers, volunteers, and participants who made the AMCIS 2019 a great experience and to the audience for such an energetic and positive discussion about the 4IR.

References

3GPP. (2020). *Release 17.* Retrieved from www.3gpp.org/release-17

Abbasi, A., Zhang, Z., Zimbra, D., Chen, H., & Nunamaker, J. F. (2012). Detecting fake websites: The contribution of statistical learning theory. *MIS Quarterly, 34*(3), 1-28.

Aleksander, I. (2004). Advances in intelligent information technology: Re-branding or progress towards conscious machines. *Journal of Information Technology*, *19*(1), 21-27.

Al-Turjman, F., Lemayian, J., Alturjman, S., & Mostarda, L. (2019). Enhanced deployment strategy for the 5G Drone-BS using artificial intelligence. *IEEE Access*, 7, 75999-76008.

Alsuhli, H. (2019). The fifth generation of mobile network as the core for the industrial revolution 4.0. *International Journal of Industrial Revolution 4.0 & Education development*, *1*(1), 1-5.

Anandarajan, M. (2002). Profiling web usage in the workplace: A behavior based artificial intelligence approach. *Journal of Management Information Systems*, *19*(1), 243-266.

Beck, R. (2018) Beyond Bitcoin: The Rise of Blockchain World, *IEEE Computer*, *51*(2), 54-58.

Benaich, N., & Hogarth, I. (2018). State of AI June 29, 2018. *State of AI*. Retrieved from https://www.stateof.ai/2018

Benaich, N., & Hogarth, I. (2019). *State of AI report June 29, 2019.* Retrieved from https://www.slideshare.net/StateofAIReport/state-of-ai-report-2019-151804430

Byrd, T., & Turner, D. 2000). Measuring the flexibility of information technology infrastructure: Exploratory analysis of a construct. *Journal of Management Information Systems*, *17*(1), 167-208.

Carson, B., Romanelli, G., Walsh, P., & Zhumaev, A. (2019). Blockchain beyond the hype: What is the strategic business value? *McKinsey*. Retrieved from https://www.mckinsey.com/business-functions/digital-mckinsey/our-insights/blockchain-beyond-the-hype-what-is-the-strategic-business-value

Casino, F., Dasaklis, T., & Patsakis, C. (2019). A systematic literature review of blockchain-based applications: Current status, classification and open issues. *Telematics and Informatics*, *26*, 55-81.

Chanson, M., Gjoen, J., Risius, M., & Wortmann, F. (2018a). Initial coin offerings (ICOs): The role of social media for organizational legitimacy and underpricing. In *Proceedings of the 39th International Conference on Information Systems*.

Chanson, M., Risius, M., & Wortmann, F. (2018b). Initial coin offerings (ICOs): An introduction to the novel funding mechanism based on blockchain technology. In *Proceedings of the 24th Americas Conference on Information Systems*.

Chen, Z., Wang, W., Yan, X., & Tian, J. (2019). *Cortex—AI on Blockchain: the Decentralized AI Autonomous System.* Retrieved from https://cryptorating.eu/whitepapers/Cortex/Cortex_AI_on_Blockchain_EN.pdf

Cho, M. (2019). South Korea Secures 4 million 5G Subscribers. *ZDNet*. Retrieved from https://www.zdnet.com/article/south-korea-secures-4-million-5g-subscribers/

Chuen, K., Lee, D. (2017). Fintech tsunami: Blockchain as the driver of the Fourth Industrial Revolution. Retrieved from https://ssrn.com/abstract=2998093

Daugherty, P., & Carrel-Billiard, M. (2019). The post-digital era is upon us: Are you ready for what's next? *Accenture*. Retrieved from https://www.accenture.com/_acnmedia/PDF-94/Accenture-TechVision-2019-Tech-Trends-Report.pdf

Dinev, T., McConnell, A. R., & Smith, H. J. (2015). Research commentary—informing privacy research through information systems, psychology, and behavioral economics: Thinking outside the “APCO” box. *Information Systems Research*, *26*(4), 639-655.

Dinh, T., Liu, R., Zhang, M., Chen, G., Ooi, B., & Wang, J. (2018). Untangling blockchain: A data processing view of blockchain systems. *IEEE Transactions on Knowledge and Data Engineering*, *30*(7), 1366-1385.

European Commission. (2018). Ethics guidelines for trustworthy AI. Retrieved from https://www.euractiv.com/wp-content/uploads/sites/2/2018/12/AIHLEGDraftAIEthicsGuidelinespdf.pdf

Expert System. (2020). *What is machine learning? A definition.* Retrieved from https://expertsystem.com/machine-learning-definition/

French, A., Risius, M., & Shim, J. P. (2020). The interaction of virtual reality, blockchain, and 5G new radio: Disrupting business and society. *Communications of the Association for Information Systems*, *46*, 603-618.

Gerber, N., Gerber, P., & Volkamer, M. (2018). Explaining the privacy paradox: A systematic review of literature investigating privacy attitude and behavior. *Computers & security* (77), 226-261.

Gill, S., Tuli, S., Xu, M., Singh, I., Singh, K., Lindsay, D., Tuli, S., Smirnova, D., Singh, M., Jain, U., Pervaiz, H., Sehgal, B., Kaila, S., Misra, S., Aslanpour, M., Mehta, H., Stankovski, V., Garraghan, P. (2019). Transformative effects of IoT, blockchain and artificial intelligence on cloud computing: Evolution, vision, trends and open challenges. *Internet of Things*, *8*, 100-118.

Glaser, F. (2017). Pervasive decentralisation of digital infrastructures: A framework for blockchain enabled system and use case analysis. In *Proceedings of the 50th Hawaii International Conference on System Sciences*.

Gresset, E. (2017). 5G networks—a new era for a diversely connected world. *Ceva-DSP.* Retrieved from https://www.ceva-dsp.com/ourblog/5g-networks-new-era-diversely-connected-world/

GSMA. (2018). The 5G era in the US. Retrieved from https://www.gsma.com/publicpolicy/resources/the-5g-era-in-the-us

HackerNoon. (2018). AI smart contracts—the past, present, and future. Retrieved from https://hackernoon.com/ai-smart-contracts-the-past-present-and-future-625d3416807b

Harlev, M. A., Sun Yin, H., Langenheldt, K. C., Mukkamala, R., & Vatrapu, R. (2018) Breaking bad: De-anonymising entity types on the bitcoin blockchain using supervised machine learning. In *Proceedings of the 51st Hawaii International Conference on System Sciences*.

Heckman, J. (2019). The national archives and records administration considers blockchain to verify records amid rise in deepfake videos. *Federal News Network*. Retrieved from https://federalnewsnetwork.com/technology-main/2019/06/nara-considers-blockchain-to-verify-records-amid-rise-in-deepfake-videos/

Hochstein, M., De, N., & Baydakova, A. (2019). Beyond KYC: Regulators set to adopt tough new rules for crypto exchanges. *Coindesk*. Retrieved from https://www.coindesk.com/beyond-kyc-global-regulators-appear-set-to-adopt-tough-new-rules-for-crypto-exchanges

Houlding, D. (2017). Blockchain, smart contracts, artificial intelligence, and machine learning in healthcare. *Intel IT Peer Network*. Retrieved from https://itpeernetwork.intel.com/blockchain-smart-contracts-artificial-intelligence-machine-learning-healthcare/

Kodama, F. (2018). Learning mode and strategic concept for the 4th industrial revolution. *Journal of Open Innovation: Technology, Market, and Complexity*, *4*(3), 1-17.

Labazova, O. (2019). Towards a framework for evaluation of blockchain implementations. In *Proceedings in the 40th International Conference on Information Systems*.

Larsen, K. R., & Bong, C. H. (2016). A tool for addressing construct identity in literature reviews and meta-analyses. *MIS Quarterly*, *40*(3), 529-551.

Li, J., Larsen, K. R., & Abbasi, A. (Forthcoming). Theory on: Designing a construct-based search engine to reduce information overload for behavioral science research. *MIS Quarterly,*

Magas, J. (2019). Blockchain and AI: Leading the way to the fourth industrial revolution against the Odds. *Cointelegraph*. Retrieved from https://cointelegraph.com/news/blockchain-and-ai-leading-the-way-to-the-fourth-industrial-revolution-against-the-odds

Mashamba-Thompson, T., & Crayton, E. (2020). Blockchain and artificial intelligence technology for novel coronavirus disease 2019 self-testing. *Diagnostics*, *10*(4), 1-4.

Narayan, D., & Cassidy, M. F. (2001). A dimensional approach to measuring social capital: Development and validation of a social capital inventory. *Current Sociology*, *49*(2), 59-102.

Nofer, M., Gomber, P., Hinz, O., & Schiereck, D. (2017). Blockchain. *Business & Information Systems Engineering*, *59*, 183-187.

Outchakoucht, A., Hamza, E., & Leroy, J. P. (2017). Dynamic access control policy based on blockchain and machine learning for the Internet of things. *International Journal of Advanced Computer Science and Applications*, *8*(7), 417-424.

Pedersen, A. B., Risius, M., & Beck, R. (2019). A ten-step decision path to determine when to use blockchain technologies. *MIS Quarterly Executive*, *18*(2), 99-115.

Penttinen, J. (2019). *5G explained*. Presented at Georgia State University.

Portes, A. (2014). Downsides of Social Capital. *Proceedings of the National Academy of Sciences*, *111*(52), 18407-18408.

Portes, A., & Landolt, P. (1996). The downside of social capital. *The American Prospect*, *26*, 18-22.

Pham, A.-D., & Ahn, H.-J. (2018). High precision reducers for industrial robots driving 4th industrial revolution: State of arts, analysis, design, performance evaluation and perspective. *International Journal of Precision Engineering and Manufacturing-Green Technology*, *5*(4), 519-533.

Risius, M. (2014). Is it really about facts? The positive side of “meforming” for turning self-disclosure into social capital in enterprise social media. In *Proceedings of the 22nd European Conference on Information Systems.*

Risius, M., Baumann, A., & Krasnova, H. (2020). Developing a new paradigm: Introducing the Intention-behaviour gap to the privacy paradox phenomenon. In *Proceedings of the 28th European Conference on Information Systems.*

Risius, M., & Beck, R. (2014). You reap what you sow? How knowledge exchange effectiveness is affected by different types of communication in enterprise social media. In *Proceedings of the 47th Hawaii International Conference on System Sciences.*

Risius, M., & Spohrer, K. (2017). A blockchain research framework: What we (don’t) know, where we go from here, and how we will get there. *Business & Information Systems Engineering*, *59*, 385-409.

PwC. (2017). Global Digital IQ Survey: 10th anniversary edition. *PwC.* Retrieved from https://www.pwc.com/sk/en/publikacie/assets/2017/pwc-digital-iq-report.pdf

Reid, F., & Harrigan, M. (2013). An analysis of anonymity in the bitcoin system. In Y. Altshuler, Y. Elovici, A. Cremers, N. Aharony, & A. Pentland (Eds.), *Security and privacy in social networks* (pp. 197-223). Berlin: Springer.

Seeger, A.-M., Pfeiffer, J., & Heinzl, A. (Forthcoming). Texting with human-like conversational agents: Designing for anthropomorphism. *Journal of the Association for Information Systems*.

SCALA Blockchain. (2017). Telecom. Retrieved from http://www.scalablockchain.com/telecom.html

Schwab, K. (2017). *The fourth industrial revolution*. New York, NY: Currency Books.

SDxCentral. (2018). What is the radio access network? *SDX Central*. Retrieved from https://www.sdxcentral.com/5g/definitions/radio-access-network/

Shafin, R., Liu, L., Chandrasekhar, V., Chen, H., Reed, J., & Zhang, J. (2020). Artificial intelligence-enabled cellular networks: A critical path to beyond-5G and 6G. *IEEE Wireless Communications*, *27*(2), 212-217.

Shim, J. P., Sharda, R., French, A. M., Syler, R. A., & Patten, K. P. (2020). The Internet of things: Multi-faceted research perspectives. *Communications of the Association for Information Systems*, *46*, 511-536.

Silverio-Fernández, M., Renukappa, S., & Suresh, S. (2018). What is a smart device? A conceptualisation within the paradigm of the Internet of things. *Visualization in Engineering*, *6*(1).

Singh, S., Sharma, P., Yoon, B., Shojafar, M., Cho, G., & Ra, I. (2020). Convergence of blockchain and artificial intelligence in IoT network for the sustainable smart city. *Sustainable Cities and Society*, *63*(10).

Smee, J. (2018). 5G NR theory and practice. In *Proceedings of the Wireless Telecommunication Symposium.*

Somdip, D. (2018). A proof of work: Securing majority-attack in blockchain using machine learning and algorithmic game theory. *International Journal of Wireless and Microwave Technologies*, *8*(5), 1-9.

Spohr, D. (2017). Fake news and ideological polarization: Filter bubbles and selective exposure on social media. *Business Information Review*, *34*(3), 150-160.

Szabo, N. (1997). Formalizing and securing relationships on public networks. *First Monday*, *2*(9).

Tapscott, D., & Tapscott, A. (2017). How blockchain will change organizations. *MIT Sloan Management Review*, *58*(2), 10-13.

Tokenpost. (2019). NEM Ventures invests in startup using blockchain and machine learning to reduce environmental footprint. *Tokenpost*. Retrieved from https://tokenpost.com/NEM-Ventures-invests-in-startup-using-blockchain-and-machine-learning-to-reduce-environmental-footprint-2450

Wang, H., Zheng, Z., Xie, S., Dai, H.-N., & Chen, X. (2018). Blockchain challenges and opportunities: A survey. *International Journal of Web and Grid Services*, *14*, 352-375.

Wang, P. (2019). On defining artificial intelligence. *Journal of Artificial General Intelligence*, *10*(2), 1-37.

Wilson, H., Daugherty, P., & Morini-Bianzino, N. (2017). The jobs that artificial intelligence will create. *Sloan Management Review*, *58*(4), 13-16.

Xu, X., Weber, I., Staples, M., Zhu, L., Bosch, J., Bass, L., Pautasso, C., & Rimba, P. (2017). A taxonomy of blockchain-based systems for architecture design. In *Proceedings in the IEEE International Conference on Software Architecture.*

Zyskind, G., Nathan, O., & Pentland, S. (2015). Decentralizing privacy: Using blockchain to protect personal data. In *Proceedings of the IEEE Security and Privacy Workshops.*

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