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The Dawning of the Digital Era

THE OBJECTIVES

This chapter discusses the following:

1) The Trendsetting Technologies and Tools for the Digital Era
2) Why Digitization Is Indispensable
3) The Connectivity and Integration Options
4) About Digitally Transformed Systems, Networks, and Environments
5) The Promising Digital Intelligence Methods
6) The Cloud-Native Principles Are Essential for Producing and Delivering Breakthrough Applications for the Impending Digital Era

Demystifying the Digitization Paradigm

With the faster maturity and solidity of digitization and digitalization technologies and tools, the dreamt digital era is all set to mesmerize the whole world. There are several path-breaking digitization and edge technologies (sensors, stickers, RFID tags, barcodes, microcontrollers, beacons, LED lights, etc.). These technological innovations and disruptions have solidly and succulently enabled the digitization movement. Thereby, today we are being surrounded by so many digital elements, which turn out to be computational, communicative, sensitive, perceptive, vision-enabled, decision-making, responsive, and active. Digital entities have facilitated mainstream computing in our everyday environments such as homes, hotels, and hospitals. All kinds of physical, mechanical, and electrical systems in our midst are being transitioned into digital assets through the above-mentioned digitization and edge technologies. It is projected that there will be trillions of digital assets on planet earth in the years to come. Then came the connectivity technologies. Resultantly digital elements are now being integrated with one another in the neighborhood and also with the cloud-hosted software services and databases over the Internet, which is being projected as the world's largest communication infrastructure. Such integration empowers digital assets to gain additional capabilities. Digital elements are publicly discoverable and network-accessible. Further on, remote monitoring, measurement, and management of digital elements are made possible. Multi-device applications, which are process-aware, business-critical, and people-centric will flourish with the proper nourishment. Digital assets become self-, surrounding- and situation-aware. Context-aware applications are bound to thrive and will be delivered to humans in an unobtrusive manner. The IoT paradigm represents the combination of digitization/edge and connectivity technologies.

Cloud-native Computing: How to Design, Develop, and Secure Microservices and Event-Driven Applications, First Edition. Pethuru Raj, Skylab Vanga, and Akshita Chaudhary.

Further on, the device ecosystem is growing fast. Today we are bombarded with a dazzling array of slim and sleek, handy and trendy devices, which are increasingly multifaceted and versatile. We have medical instruments, defense equipment, appliances, machineries, kitchen utilities, consumer electronics, personal gadgets and gizmos, handhelds, wearables, implantables, portables, etc., in large quantities. Robots, digital assistants with speech recognition capability, drones, and other edge devices are found in our everyday environments. These devices are also integrated with cloud-based applications. Worldwide market watchers, researchers, and analysts have estimated that there will be billions of connected devices. Interestingly, we have billions of smartphones connected to the Internet. These empowered digital entities and connected devices are being termed the Internet of Things (IoT) sensors and devices, respectively. Typically, IoT sensors are resource-constrained whereas IoT devices are resource-intensive. IoT sensors are for capturing operational aspects of digital assets. In addition, IoT sensors capture environment data in which digital assets are situated. IoT devices have more memory and storage capacities and processing capability, thereby they can participate and contribute to data processing individually and collectively.

IoT devices will naturally interact with human beings also with the emergence of human–machine interfaces (HMIs). Devices will get the power to find and interact with others in the vicinity to accomplish better and bigger things for people. Through digitization and connectivity technologies, every common and casual thing in our personal, professional, and social environments becomes digitized and connected. Ordinary things become extraordinary in providing enhanced services. Dumb things become animated. Precisely speaking, everything becomes smart, every device becomes smarter, and every man becomes the smartest. A variety of automation, augmentation, and acceleration will happen with the skilled usage of the distinct advancements in the IoT space.

Delineating the Digitalization Technologies

We have discussed digitization and edge technologies in the previous section. Also, with the local as well as remote connectivity technologies, how the IoT paradigm is promising a lot for the world is deliberated. It is no exaggeration to state that the human race is to benefit immensely through the hugely potential IoT idea. The IoT phenomenon is to ultimately result in the digital era, which is going to be software-defined. In this section, we are to focus on digitalization technologies and how they are going to shape the digital world. When digitization and digitalization technologies converge seamlessly and spontaneously, there is a possibility for an explosion of hitherto unheard software applications and industry use cases. Newer IT products, solutions and services will emerge and evolve fast to tackle existing and emerging people's problems, societal challenges, and business expectations. Fresh use cases will be unearthed and articulated through technological innovations. The real digital transformation will happen and hence business and people transformations are to see the grandiose reality.

With digitized objects (interchangeably referred to as IoT sensors and devices) abound in our living environments and workplaces, they collaborate, correlate, and corroborate, resulting in a massive amount of multi-structured data. For the digital transformation goals to be realized, the basic tenet is to transition digit data into information and knowledge. Digitalization technologies play a very vital role. There are digitalization technologies and tools for performing data capture, cleansing, preprocessing, storage, processing, analytics, and visualization tasks. That is, the process of transitioning data to information and knowledge is highly optimized. There is a bevy of

automated tools fully complying with various digitalization technologies. Thus, the goal of translating data to knowledge gets speeded up and simplified through the adroit usage of digitalization technologies. Here is a list of prominent digitalization technologies:

1) Artificial intelligence (AI) algorithms, frameworks, accelerators, and libraries
2) Big, fast, and streaming data analytics methods and platforms
3) Software-defined cloud infrastructures
4) Digital twins
5) Cybersecurity
6) Cloud-native computing
7) Edge computing
8) Serverless computing
9) Microservices architecture (MSA)
10) Event-driven architecture (EDA)
11) Blockchain technology
12) 5G communication

These technologies come in handy for extracting actionable insights into time out of voluminous data. The knowledge discovered gets disseminated to the concerned systems and people in a time in order to empower them to ponder about the next course of action. This set of cutting-edge technologies is seen as the key contributor and prime method for realizing intelligent business workloads and IT services. Digitized elements and connected devices are also being made intelligent in their actions and reactions through knowledge discovery technologies. Thus, data and learning from data are seen as two crucial enablers for the ensuing intelligent era. Connected assets are bountifully liable for probing and manipulation. With the pervasive Internet communication infrastructure, remote attacks through networks are getting accelerated. Thus, for the digital era to really shine, cyberterrorism activities must be eliminated through competent security technologies and tools. Thus, the field of cybersecurity [1] is gaining prominence these days.

Trendsetting Technologies for the Digital Era

We have discussed both digitization and digitalization technologies. They are together called digital technologies. One of the most visible and value-adding trends in IT is nonetheless the digitization aspect. All kinds of concrete items in our personal, professional, and social environments are being digitized through digitization technologies to be communicative, sensitive, perceptive, and responsive. These days, due to the unprecedented maturity and stability of a host of path-breaking technologies such as miniaturization, sensing, actuation, connectivity, and intermediation technologies, every tangible thing in our environments has grasped the inherent power of finding and binding with one another in its vicinity as well as with remote objects via networks purposefully and on need basis to uninhibitedly share their distinct capabilities toward the goal of providing deeper automation. With such an accumulation of digitized entities in and around us, human beings are all set to become the smartest in their deals, decisions, and deeds. In this section, the most prevalent and pioneering trends and transitions in the IT landscape will be discussed. Especially, the digitization technologies and techniques are given a sufficient push.

As widely reported, there are several delectable transitions in the IT landscape. The consequences are definitely vast and varied. First, it is the incorporation of nimbler and next-generation

features and functionalities into the existing IT solutions. Second, the eruption of altogether new IT products and solutions for humanity. These have the intrinsic capabilities to bring forth numerous subtle and succinct transformations for businesses as well as people.

IT Consumerization: There are much-discoursed and deliberated reports detailing the diversity and availability of mobile devices (smartphones, tablets, digital assistants, wearables, drones, robots, etc.) and their management platforms. Today we have millions of mobile apps. This trend is ultimately empowering people in their daily works and walks. The ubiquitous information access is made possible. Further on, the IT infrastructures are being tweaked accordingly in order to gracefully support this strategically sound movement. There are some challenges for IT administrators in fulfilling the device explosion. That is, IT is steadily becoming an inescapable part of consumers directly and indirectly. And the need for robust and resilient device management software with the powerful emergence of "bring your own device (BYOD)" paradigm is being felt and is being insisted across. With smartphones emerging as the most pervasive input and output tools for everyone across the world, there is a myriad of development platforms, cross-compilers, programming and markup languages, enabling frameworks, tools, and lightweight operating systems in the fast-moving mobile space. Precisely speaking, IT is not only for businesses but also for every human being. 5G communication [2] capabilities come in handy in ubiquitous and mobile access to digital applications and services

IT Commoditization: This is another cool trend penetrating the IT industry. Due to the sudden surge of big data analytics (BDA) requirements, there is a demand for large-scale computing and storage. Instead of using expensive hyperconverged infrastructures (HCIs) (alternative referred to as appliances), there is a movement toward leveraging commodity server machines and their clusters. HCIs are basically beset by a high total cost of ownership (TCO) and less return on investment (ROI).

This is in line with the goal of IT optimization. The IT resource utilization has been on the lower side, and there came a series of technologies to bring in highly optimized and organized IT. Such an optimization process is to bring down IT cost sharply. This is the crux of the cloud computing paradigm. This is a new kind of consolidated, centralized, automated, and shared computing model. Virtualization and containerization concepts emerged and evolved fast in order to fulfil the much-touted optimization goal. With these compartmentalization technologies (explained later), the IT resource utilization efficiency is going up steadily. These impactful techniques have penetrated every IT module including networking, security, and storage components.

The intelligence embedded in IT hardware elements is being abstracted and centralized through hypervisor software solutions. Hardware systems are thus software-enabled to be easily manipulated and programmed. With this transition, all the hardware resources in any data center can be easily updated, upgraded, replaced, substituted, and composed for quickly fulfilling different requirements and use cases. Commoditized IT solutions are relatively cheap and hence the IT affordability target is realized along with a number of other advantages. That is, the future IT data centers and server farms are going to be stuffed with a number of commodity servers, storages, and network solutions.

IT Compartmentalization (Virtualization and Containerization): The "divide and conquer" method has been the most versatile and rewarding mantra in the IT field. Abstraction is another powerful and established technique in the IT space. The widely used virtualization, which had laid a stimulating and sustainable foundation for the raging cloud idea, is actually hardware virtualization. The virtualization has penetrated into storage appliances, network components and security solutions. That is, entire data centers are methodically virtualized. There are a few serious drawbacks with virtualization.

Then came the aspect of containerization being represented through the popular Docker platform. Containerization is the operating system (OS)-level virtualization. Containers are lightweight and hence attain the native performance of the physical machines. The real-time horizontal scalability is being facilitated by the concept of containerization. Containerization has surmounted many of the limitations of virtualization. Containerization is enabling the originally expressed goals of cloud computing.

IT Industrialization: The cloud idea has laid down a stellar foundation for IT industrialization. Consolidating, virtualizing, and/or containerizing and centralizing all kinds of IT systems, putting them on-premises and/or off-premises, operating them in a shared and automated fashion, delivering them in an online and on-demand manner, continuously adding newer capabilities by bringing forth fresh technologies and tools, etc., lead toward industrialized IT.

IT Digitization and Distribution: As explained in the beginning, digitization has been an ongoing process and it has quickly generated and garnered a lot of market and mind shares. Digitally enabling everything around us induces a dazzling array of cascading and captivating effects in the form of cognitive and comprehensive transformations for businesses as well as people. With the growing maturity and affordability of scores of edge technologies, every common thing in our personal, social, and professional environments is becoming digitized.

Similarly, the distribution aspect too gains more ground. Due to its significant advantages in crafting and sustaining a variety of large-scale business applications, the distributed computing phenomenon has become popular. Distributed applications, though weighed down by security implications, are good for fulfilling various nonfunctional requirements (NFRs) such as availability, scalability, modifiability, and accessibility. Lately, there is a bevy of software architectures, frameworks, patterns, practices, and platforms for realizing distributed applications. With blockchain grabbing the attention of many, decentralization is picking up for producing decentralized applications.

Why Digitization Is Indispensable

Ultimately, all kinds of perceptible objects in our everyday environments will be empowered to be remotely identifiable, reachable, readable, recognizable, addressable, and controllable. Such profound empowerment will bring forth real transformations for the total human society, especially in establishing and sustaining smarter environments, such as smarter homes, buildings, hospitals, classrooms, offices, and cities. Suppose a man-made or natural disaster occurs. If everything in the disaster area is digitized, then it becomes possible to rapidly determine what exactly has happened, the intensity of the disaster, and the hidden risks in the affected environment. Any worthwhile information extracted provides a way to properly plan and proceed insightfully, reveals the extent of the destruction, and conveys the correct situation of the people therein. The knowledge gained would enable the rescue and emergency team leaders to cognitively contemplate appropriate decisions and plunge into actions straightaway to rescue as much as possible, thereby minimizing damages and losses to properties and people.

In short, digitization will substantially enhance our decision-making capability in our personal as well as professional lives. Digitization also means that the ways we learn and teach are change profoundly, energy usage will become knowledge-driven so that green goals can be met more smoothly, and the security and safety of noble things will go up considerably. As digitization becomes pervasive, our living, relaxing, working, eating, and socializing places will be filled up with a variety of electronics including environment-monitoring sensors, actuators, disappearing controllers,

projectors, cameras, appliances, high-definition IP TVs, and robots. In addition, items such as furniture and packages will become empowered by attaching state-of-the-art LEDs, beacons, infinitesimal sensors, specialized electronics, and communication modules. Whenever we walk into such kinds of enlightened environments, the devices we carry and even our e-clothes will enter into a collaboration mode to form wireless and ad hoc networks with the digitized objects in that environment. For example, if someone wants to print a document from his smartphone or tablet, and he enters a room where a printer is installed, the smartphone will automatically begin a conversation with the printer, check its competencies and compatibilities, and send the documents to be printed. The smartphone will then alert the owner about the neat and nice accomplishment.

Digitization will also provide enhanced care, comfort, choice, and convenience. Next-generation healthcare services will demand deeply connected and cognitive solutions. For example, ambient assisted living (AAL) is a new prospective application domain where lonely, aged, diseased, bedridden, and debilitated people living at home will receive a remote diagnosis, care, and management by medical doctors, nurses, and other caregivers who remotely monitor patients' health and physiological parameters.

People can track the progress of their fitness routines. Taking decisions becomes an easy and timely affair with the prevalence and participation of connected solutions that benefit knowledge workers immensely. All the secondary and peripheral needs will be accomplished in an unobtrusive manner so that people nonchalantly focus on their primary activities. However, there are some areas of digitization that need some attention. One is the goal of energy efficiency. Green solutions and practices are being insisted upon everywhere these days, and IT is one of the principal culprits in wasting a lot of precious energy due to the pervasiveness of commoditized IT servers and connected devices. Data centers armed with a large number of server machines, storage appliances, and networking solutions are bound to consume a lot of electricity and dissipate more heat into the fragile environment. So, green IT has become a hot subject for deeper study and research across the globe. Another prime area of interest is remote monitoring, management, and enhancement of empowered devices. With the number of devices in our everyday environments growing at an unprecedented scale, their real-time administration, configuration, activation, monitoring, management, patching, and repair (if any problem arises) can be eased considerably with effective remote connection and correction competencies.

Deeper Connectivity: The connectivity trait has risen dramatically. The network topologies and technologies are consistently expanding and empowering their participants and constituents to be highly productive. There are unified, ambient, and autonomic communication technologies emanating from worldwide research organizations and labs. These transitions draw the attention of executives and decision-makers in a bigger way. All kinds of digitized elements are intrinsically empowered to form ad hoc networks for accomplishing specialized tasks in a simpler and smarter manner. There are a variety of network and security solutions in the form of load balancers, switches, routers, gateways, proxies, firewalls, etc., and these are nowadays available as hardware and software appliances.

Device Middleware or Device Service Bus (DSB) is the latest buzzword enabling seamless and spontaneous connectivity and integration between disparate and distributed devices. That is, device-to-device (in other words, machine-to-machine [M2M]) communication is the talk of the town. The interconnectivity-facilitated interactions among diverse categories of devices precisely portend a litany of supple, smart, and sophisticated applications for people. Due to the multiplicity and heterogeneity of devices, the device complexity is to rise further. Device middleware solutions are being solicited in order to substantially enable devices to talk to one another in the vicinity and with remote ones through appropriate networking.

Software-Defined Networking (SDN) is the latest technological trend captivating professionals to have a renewed focus on this emerging yet compelling concept. With clouds being strengthened as the core, converged and central IT infrastructure, the scenarios for device-to-cloud interactions are fast-materializing. This local, as well as remote connectivity, empowers ordinary articles to become extraordinary objects by distinctively communicative, collaborative, and cognitive.

Another associate topic is **virtual network functions (VNFs)**. With containerization, we are tending toward **cloud-native network functions (CNFs)**. Network capabilities and resources are being shrewdly used to achieve more with less. Network slicing is seen as a paradigm shift. Newer network functionalities are being realized through CNFs. That is, network functions are developed as microservices [3] and they are containerized. With the leverage of container orchestration platform solutions such as Kubernetes, CNFs are portrayed as the way forward for communication service providers to be proactive in offering premium services to their clients and consumers. With such network segmentation/partition, network resource usage productivity goes up significantly. Thus, networks are being readied through versatile technological solutions to be adaptive in order to succulently support smart systems and environments.

Service Enablement: Physical devices at the ground level are being seriously service-enabled in order to uninhibitedly join in the mainstream computing tasks. That is, devices, individually and collectively, could become service providers or publishers, brokers and boosters, and consumers. The prevailing and pulsating idea is that any service-enabled device in a physical environment could interoperate with others in the vicinity as well as with remote devices and applications. Services could abstract and expose only the specific capabilities of devices through service interfaces while service implementations are hidden from user agents. Such a smart separation enables any requesting device to see only the capabilities of target devices, and then connect, access, and leverage those capabilities to achieve business or people services. The service enablement completely eliminates all dependencies so that devices could interact with one another flawlessly and flexibly. Further on, application interoperability gets accomplished through the widely adopted service-enablement facet. Ultimately, the majority of next-generation, enterprise-scale, mission-critical, process-centric, and multi-purpose applications are being assembled out of multiple discrete and complex services.

The Future Internet: As digitization gains more accolades and success, all sorts of everyday objects are being connected with one another as well as with scores of applications running in cloud environments. That is, everything is becoming a data supplier for the next-generation applications, thereby becoming an indispensable ingredient individually as well as collectively in consciously conceptualizing and concretizing smarter applications. There are several promising implementation technologies, standards, platforms, and tools enabling the realization of the IoT vision. The probable outputs of the IoT field are a cornucopia of smarter environments such as smarter offices, homes, hospitals, retail stores, cities, etc. Cyber-physical systems (CPSs), ambient intelligence (AmI), ubiquitous computing (UC), and pervasive and sentient computing are some of the related concepts encompassing the ideals of IoT.

In the upcoming era, computers, communication modules, and multifaceted sensors will be facilitating the right decision-making. Computers of different sizes, looks, capabilities, and interfaces will be fitted, glued, implanted, and inserted everywhere to be coordinative, calculative, consistent, and coherent in their actions. The interpretation and involvement of humans in operationalizing these sophisticated and sentient objects are almost zero. With autonomic IT infrastructures, more intensive and insightful automation and orchestration are bound to happen. Devices collectively will also handle all kinds of everyday needs. Drones will be pervasive and humanized robots extensively will get used in order to fulfil our daily physical chores.

On summarizing, the Internet is fast expanding. Manufacturing machines, medical instruments, defense equipment, home appliances, everyday devices, specialized robots and drones, kitchen utensils, consumer electronics, infinitesimal sensors, etc., will be linked up with the Internet in order to get more people-centric use cases. With the addition of billions of electronic devices and trillions of digitized items, the future Internet is going to be humongous and complex.

Tending Toward the Trillions of IoT Devices: The table below [4] lists the prominent and dominant IoT technologies for realizing IoT devices and applications.

1) The realization technologies are maturing (miniaturization, instrumentation, connectivity, remote programmability/service-enablement/APIs, sensing, vision, perception, analysis, knowledge-engineering, decision-enablement, etc.)
2) A flurry of edge technologies (sensors, stickers, specks, smart dust, codes, chips, controllers, LEDs, tags, actuators, etc.)
3) Ultra-high bandwidth communication technologies (wired as well as wireless [4G, 5G, etc.])
4) Low-cost, power, and range communication standards (LoRa, LoRaWAN, NB-IoT, 802.11x Wi-Fi, Bluetooth Smart, ZigBee, Thread, NFC, 6LowPAN, Sigfox, Neul, etc.)
5) Powerful network topologies, Internet gateways, integration and orchestration frameworks, and transport protocols (MQTT, UPnP, CoAP, XMPP, REST, OPC, etc.) for communicating data and event messages
6) A variety of IoT application enablement platforms (AEPs) with application building, deployment and delivery, data and process integration, application performance management, security, orchestration, and messaging capabilities
7) Event processing and streaming engines for event message capture, ingestion, processing, etc.
8) A bevy of IoT data analytics platforms for extracting timely and actionable insights out of IoT data
9) Edge/fog analytics through edge clouds
10) IoT gateways, platforms, middleware solutions, databases, and applications on cloud environments

Source: Modified from [4].

Envisioning Millions of Software Services: With the accelerated adoption of MSA and EDA, enterprise-scale applications are being expressed and exposed as a dynamic collection of fine-grained, self-contained, loosely coupled, network-accessible, publicly discoverable, API-enabled, composable, and lightweight services. Not only business applications and IT services but also embedded applications are increasingly built as a collection of microservices. As reported earlier, all kinds of devices express their functionalities as services. Thus, the number of device services is going to grow rapidly. That is, hardware resources are being software-defined in order to incorporate the much-needed flexibility, maneuverability, and extensibility. This arrangement of preparing event-driven microservices and composing them to arrive at relevant applications is all set to lay down a stimulating and sustainable foundation for producing next-generation software applications out of distributed microservices. The emergence of the scintillating concepts such as Docker containers, container orchestration platforms, and DevOps is to lead the realization of cloud-native applications in conjunction with the MSA and EDA [5] patterns.

The disruptions and transformations brought in by the series of delectable advancements are really mesmerizing. IT has touched every small or big entity decisively in order to produce context-aware, service-oriented, event-driven, knowledge-filled, people-centric, and cloud-hosted applications. Data-driven insights and insights-driven enterprises are indisputably the new normal.

Infrastructure Optimization: The entire IT stack has been going for a makeover periodically. Especially on the infrastructure front, due to the closed, inflexible, and monolithic nature of

conventional IT infrastructures, there are concerted efforts being undertaken by many in order to untangle them into modular, open, extensible, converged, and programmable infrastructures. Another worrying factor is the underutilization of expensive IT infrastructures (servers, storages, and networking solutions). With IT becoming ubiquitous for automating most of the tasks across industry verticals, the problem of IT sprawl has gone up considerably and they are mostly underutilized and sometimes even unutilized for a long time. Having understood the wastage issue pertaining to IT infrastructures, the concerned have plunged into unveiling versatile and venerable measures for enhanced utilization and infrastructure optimization. Infrastructure rationalization and simplification are related activities. That is, next-generation IT infrastructures are being realized through consolidation, centralization, federation, virtualization, containerization, automation, and sharing. To bring in more flexibility, software-defined infrastructures are being proclaimed and prescribed these days.

With the faster spread of BDA platforms and applications, commodity hardware is being insisted for big data storage and processing. That is, we need low-cost and power infrastructures with supercomputing capability and virtually infinite storage. The answer is that all kinds of underutilized servers are collected and clustered together to form a dynamic and huge pool of server machines to efficiently tackle the increasing and intermittent needs of computation. Precisely speaking, clouds are the highly optimized and organized infrastructures that fully comply with the evolving expectations elegantly and economically. The cloud technology, though not a new one, represents a cool and compact convergence of several proven technologies to create a spellbound impact on both business and IT. Clouds emerge as the one-stop IT solution for all kinds of business modernization requirements. Cloudification represents the virtual IT era. As there is a tighter coupling between the physical and cyber worlds, the distinct contributions of the cloud paradigm are definitely vast and varied.

The tried and tested technique of "divide and conquer" in software engineering is steadily percolating to hardware engineering. Decomposition of physical machines into a collection of sizable and manageable virtual machines/containers for enhanced resource utilization and on the other hand, these segregated virtual machines can be aggregated to create virtual supercomputers. The extreme elasticity, extensibility, scalability, availability, adaptability, and agility of the cloud idea are good signs for the future of IT.

Finally, software-defined cloud centers see the light with the faster maturity and stability of a number of implementation technologies. To attain the originally envisaged goals, researchers are proposing to incorporate software wherever needed in order to bring in the desired separations and sophistication so that a significantly higher utilization level can be reached. When the utilization rate goes up, the cost is bound to come down. In short, the longstanding target of infrastructure programmability can be met with the embedding of intelligent software so that the infrastructure manageability, serviceability, and sustainability tasks become easier and more economical.

Data Analytics: With the amount of digital data getting generated every day projected to be in the range of exabytes, it is important for any corporate to collect, cleanse, and crunch the data in order to be digitally transformed in its strategy-making, planning and execution. We cannot afford to lose any data anymore. All kinds of internal as well as external data have to be meticulously gathered and processed in order to extricate actionable insights out of data heaps. Machine, device, sensor, actuator, business, social, operational, transactional and analytical data have to be consciously gleaned and subjected to a variety of deeper investigations to uncover useful and usable insights out of growing data volumes. Data are predominantly multi-structured. Also, data are categorized as big, fast and streaming data. Batch processing of big data has been the norm thus

far. With technological advancements, big data also can be processed and mined quickly. That is, real-time analytics of big data is made possible. Further on, we have fast and streaming data and they are analyzed in time as the timeliness and trustworthiness of data are essential to take correct decisions. Data typically lose their value with time. Thus, real-time analytics becomes dominant and deftly handled.

As we all know, the big data paradigm is opening up a fresh set of opportunities for businesses. The key challenge in front of businesses is how to efficiently and rapidly capture, process, analyze, and extract tactical, operational as well as strategic insights in time to act swiftly and sagaciously with all the confidence and clarity. In the recent past, there are experiments using the emerging concept of in-memory computing. For a faster generation of insights out of a massive amount of multi-structured data, new entrants such as in-memory and in-database analytics are highly reviewed and recommended. The new mechanism insists on putting all incoming data in memory instead of storing it in local or remote databases so that the major barrier of data latency gets eliminated.

Big Data Analytics (BDA): The big data paradigm has become a big topic across nearly every business domain. IDC defines big data computing as a set of new-generation technologies and architectures, designed to economically extract value from very large volumes of a wide variety of data by enabling high-velocity capture, discovery, and/or analysis. There are three core components in big data: the data itself, the analytics of the data captured and consolidated, and the articulation of insights oozing out of data analytics processes. There are robust products and services that can be wrapped around one or all of these big data elements. Thus, there is a direct connectivity and correlation between the digital universe and the big data idea sweeping the entire business scene. The vast majority of new data being generated as a result of digitization is unstructured or semi-structured. This means there is a need arising to somehow characterize or tag such kinds of multi-structured big data to be useful and usable. This empowerment through additional characterization or tagging results in metadata, which is one of the fastest-growing subsegments of the digital universe though metadata itself is a minuscule part of the digital universe. IDC believes that by 2022, a third of the data in the digital universe will have big data value, only if it is tagged and analyzed. There will be routine, repetitive, redundant data and hence not all data is necessarily useful for BDA. However, there are some specific data types that are princely ripe for big analysis such as:

Surveillance Footage: Generic metadata (date, time, location, etc.) is automatically attached to video files. However, as IP cameras continue to proliferate, there is a greater opportunity to embed more intelligence into the camera on the edges so that footage can be captured, analyzed, and tagged in real time. This type of tagging can expedite crime investigations for security insights, enhance retail analytics for consumer traffic patterns and, of course, improve military intelligence as videos from drones across multiple geographies are compared for pattern correlations, crowd emergence, and response or measuring the effectiveness of counterinsurgency.

Embedded and Medical Devices: In future, sensors of all types including those that may be implanted into the body will capture vital and non-vital biometrics, track medicine effectiveness, correlate bodily activity with health, monitor potential outbreaks of viruses, etc., all in real time, thereby realizing automated healthcare with prediction and precaution.

Entertainment and social media: Trends based on crowds or massive groups of individuals can be a great source of big data to help bring to market the "next big thing," help pick winners and losers in the stock market, and even predict the outcome of elections all based on information that users freely publish through social outlets.

Consumer Images: We say a lot about ourselves when we post pictures of ourselves or our families or friends. A picture used to be worth a thousand words but the advent of big data has introduced a significant multiplier. The key will be the introduction of sophisticated tagging algorithms that can analyze images either in real time when pictures are taken or uploaded or en masse after they are aggregated from various websites.

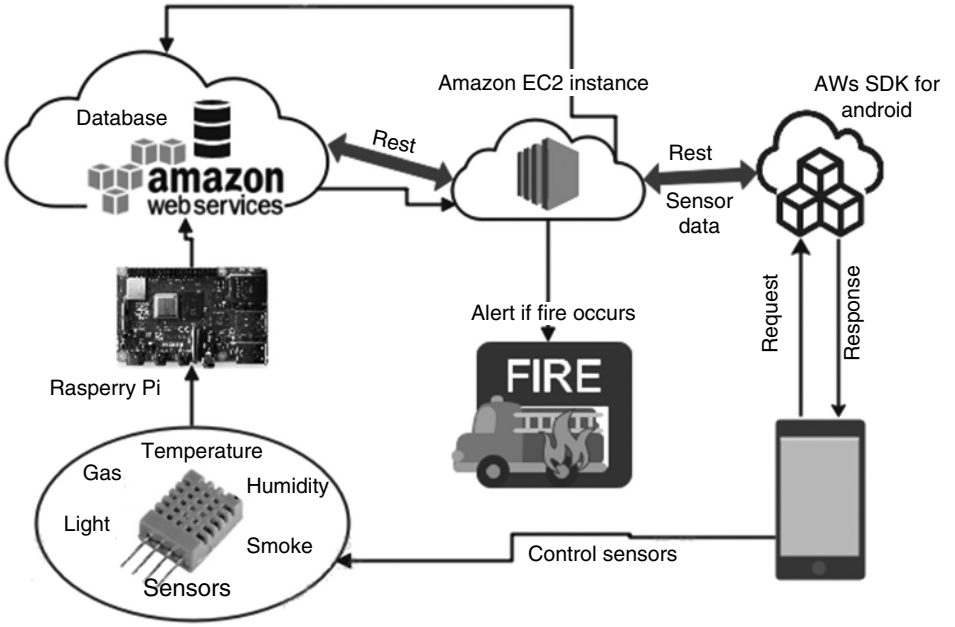
Data empowers Consumers: Besides organizations, digital data helps individuals navigate the maze of modern life. As life becomes increasingly complex and intertwined, digital data will simplify the tasks of decision-making and actuation. The growing uncertainty in the world economy over the last few years has shifted many risk management responsibilities from institutions to individuals. In addition to this increase in personal responsibility, other pertinent issues such as life insurance, healthcare, retirement, etc., are growing evermore intricate increasing the number of difficult decisions we all make very frequently. The data-driven insights come in handy in difficult situations for consumers to wriggle out. Digital data, hence, is the foundation and fountain of the knowledge society.

Power Shifts to the Data-Driven Consumers: Data is an asset for all. Organizations are sagacious and successful in promptly bringing out the premium and people-centric offerings by extracting operational and strategically sound intelligence out of accumulated business, market, social, and people data. There is a gamut of advancements in data analytics in the form of unified platforms and optimized algorithms for efficient data analysis. There are plenty of data virtualization and visualization technologies. These give customers enough confidence and ever-greater access to pricing information, service records and specifics on business behavior and performance. With the new-generation data analytics being performed easily and economically in cloud platforms and transmitted to smartphones, the success of any enterprise or endeavor solely rests with knowledge-empowered consumers.

Consumers Delegate Tasks to Digital Concierges: We have been using a myriad of digital assistants (digital assistants, smartphones, wearables, etc.) for a variety of purposes in our daily life. These electronics are of great help in crafting applications and services. Data-driven smart applications will enable these new-generation digital concierges to be expertly tuned to help us in many things in our daily life.

Source: andrew_rybalko/Adobe Stock.

As articulated above, there are integrated platforms and databases for performing real-time analytics on big data. Timeliness is an important factor for information to be beneficially leveraged. The appliances and HCIs are in general high-performing, thus guaranteeing higher throughput in all they do. Here too, considering the need for real-time emission of insights, several product vendors have taken the route of software as well as hardware appliances for substantially accelerating the speed with which the next-generation BDA get accomplished. A sample of how cloud-based data analytics contributes to establishing and sustaining smarter homes is depicted in the following diagram.



In the business intelligence (BI) domain, apart from realizing real-time insights, analytical processes and platforms are being tuned to bring forth insights that invariably predict something to happen for businesses in the near future. All these advancements enable executives and other stakeholders to proactively and pre-emptively formulate well-defined schemes and action plans, fresh policies, new product offerings, premium services, and viable and value-added solutions based on data-driven insights. Prescriptive analytics, on the other hand, is to assist business executives in prescribing and formulating ways and means of achieving what is predicted.

IBM has introduced a new computing paradigm "stream computing" in order to capture streaming and event data on the fly and to come out with usable and reusable patterns, hidden associations, tips, alerts and notifications, impending opportunities as well as threats, etc., in time for executives and decision-makers to contemplate appropriate countermeasures. The table below clearly tells why cloud centers are efficient and effective for doing IoT data analytics.

- **Agility and Affordability:** No capital investment in large-size infrastructures for analytical workloads. Just use and pay. Quickly provisioned and decommissioned once the need goes down.
- **Data Analytics Platforms in Clouds:** Therefore, leveraging cloud-enabled and ready platforms (generic or specific, open or commercial-grade, etc.) is fast and easy.
- **NoSQL and NewSQL Databases and Data Warehouses in Clouds:** All kinds of database management systems and data warehouses in cloud speed up the process of next-generation data analytics. Database as a service (DaaS), data warehouse as a service (DWaaS), business process as a service (BPaaS) and other advancements lead to the rapid realization of analytics as a service (AaaS).
- **WAN Optimization Technologies:** There are WAN optimization products for quickly transmitting large quantities of data over the Internet infrastructure.
- **Social and Professional Networking Sites** are running in public cloud environments
- **Enterprise-Class Applications in Clouds:** All kinds of customer-facing applications are cloud-enabled and deployed in highly optimized and organized cloud environments.

- **Anytime, Anywhere, Any Network and Any Device Information and Service Access** is being activated through cloud-based deployment and delivery.
- **Cloud Integrators, Brokers, and Orchestrators:** There are products and platforms for seamless interoperability among geographically distributed cloud environments. There are collaborative efforts toward federated clouds and the Intercloud.
- **Sensor/Device-to-Cloud Integration Frameworks** are available to transmit ground-level data to cloud storage and processing.

Artificial Intelligence (AI): There are other noteworthy developments in the enigmatic IT space. We discussed big data comprising both historical and current data. All kinds of deterministic and diagnostic analytics are being realized through big and real-time data analytics platforms. There are techniques and tips galore for extracting useful information out of big data in time.

With machine and deep learning (ML/DL) algorithms (a part of the AI discipline), we are heading toward the era of prognostic, predictive, prescriptive, and personalized insights out of big data. Clustered computers in conjunction with pioneering ML and DL algorithms can pierce through data heaps to bring forth something useful for people. Primarily, prediction and prescription become a new normal. The domain of computer vision gets a strong boost with the general availability of DL algorithms. Similarly, the natural language processing (NLP) discipline is gaining a lot of attention these days due to the path-breaking DL algorithms. With the explosion of IoT data, the various improvisations in the AI space are to come in handy in unambiguously understanding, continuously learning, expertly reasoning out, and proposing new thesis. Thus, building and deploying cognitive systems and services become easier with the convergence of IoT and AI concepts. AI algorithms are capable of doing real-time analytics on all kinds of data emanating from different and distributed sources. The growing maturity of the AI domain and the faster proliferation of connected devices in our everyday places have laid down a sustainable foundation for smarter systems, networks, and environments.

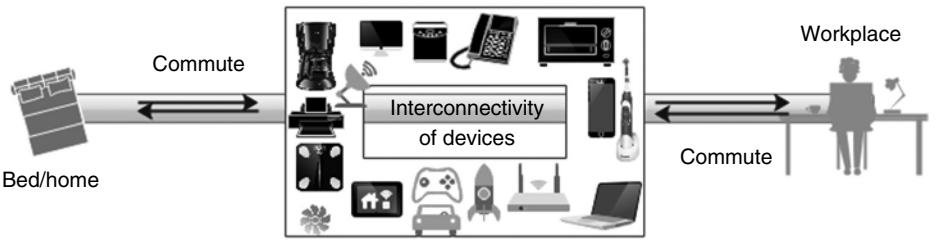
Edge/Fog Computing: As accentuated before, there are plenty of resource-constrained devices in our environments. Similarly, we are being bombarded with resource-intensive devices in our personal, social, and professional locations. The brewing trend is that clustering different resource-intensive devices to form a kind of cloud for acquiring multi-structured data from resource-constrained devices in that environment. Thereafter, processing the collected and cleansed data in order to take quick and correct decisions is becoming the new normal. Here come various valid reasons why data analytics of device data has to be accomplished through edge/fog device clouds:

- **Volume and Velocity:** Ingesting, processing, and storing such huge amounts of data which is gathered in real time.
- **Security:** Devices can be located in sensitive environments, control vital systems or send private data. With the number of devices and the fact they are not humans who can simply type a password, new paradigms, strict authentication, and access control must be implemented.
- **Bandwidth:** If devices constantly send the sensor and video data, it will hog the Internet and cost a fortune. Therefore, edge analytics approaches must be deployed to achieve scale and lower response time.
- **Real-Time Data Capture, Storage, Processing, Analytics, Knowledge Discovery, Decision-making, and Actuation**
- **Less Latency and Faster Response**
- **Context-Awareness Capability**

- **Combining Real-Time Data with Historical State:** There are analytics solutions which handle batches quite well and some tools that can process streams without historical context. It is quite challenging to analyze streams and combine them with historical data in real time.
- **Power Consumption:** Cloud computing is energy-hungry and it is a concern for a low-carbon economy.
- **Data Obesity:** In a traditional cloud approach, a huge amount of untreated data is pumped blindly into the cloud that is supposed to have magical algorithms written by data scientists. This vision is really not the best efficient and it is much wiser to pretreat data at a local level and to limit the cloud processes to a strict minimum.

Thus, edge computing and analytics through edge device clouds are flourishing with burgeoning industrial and people-centric use cases.

There are continuous improvisations and innovations in the technology space. Newer technologies open up fresh possibilities and opportunities for businesses as well as people to embark on deeper and decisive automation. The following diagram pictorially illustrates how devices talking to one another and also with remotely held cloud applications can lead to the realization of numerous sophisticated services.



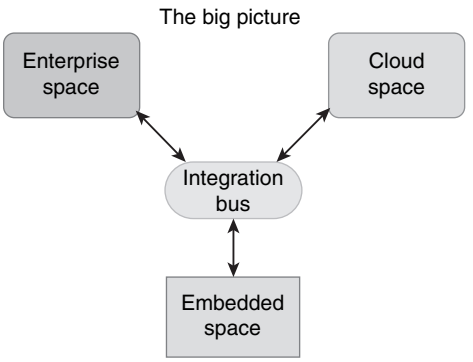
The Connectivity and Integration Options

It is forecast that there will be a dazzling array of devices in large numbers and zillions of digitized objects in the years ahead. They ought to be seamlessly and spontaneously connected and integrated in order to voluntarily share their unique capabilities with others in order to fulfill complex processes. Here is a gist of integration scenarios.

- Multi-Sensor Fusion: Heterogeneous, multifaceted, and distributed sensors talk to one another to create sensor mesh to solve complicated problems.
- Sensor-to-Cloud (S2C) Integration: CPSs will emerge at the intersection of the physical and virtual/cyber worlds.
- Device-to-Device (D2D) Integration: With the device ecosystem on the rise, the D2D integration is important.
- Device-to-Enterprise (D2E) Integration: In order to have remote and real-time monitoring, management, repair, and maintenance, and to enable decision-support and expert systems, ground-level heterogeneous devices have to be synchronized with control-level enterprise packages such as Enterprise Resource Planning (ERP), Supply Chain Management (SCM), Customer Relationship Management (CRM), and Knowledge Management (KM).
- Device-to-Cloud (D2C) Integration: As most of the enterprise systems are moving to clouds, the device-to-cloud (D2C) connectivity is gaining importance.

- Cloud-to-Cloud (C2C) Integration: Disparate, distributed, and decentralized clouds are getting connected to provide better prospects.
- Mobile Edge Computing (MEC) [6], Cloudlets, and Edge Cloud Formation through the clustering of heterogeneous edge/fog devices.

The Big Picture: With the cloud space growing fast as the next-generation environment for application design, development, deployment, integration, management, and delivery, the integration scenario is being visualized as pictorially illustrated in the next diagram.



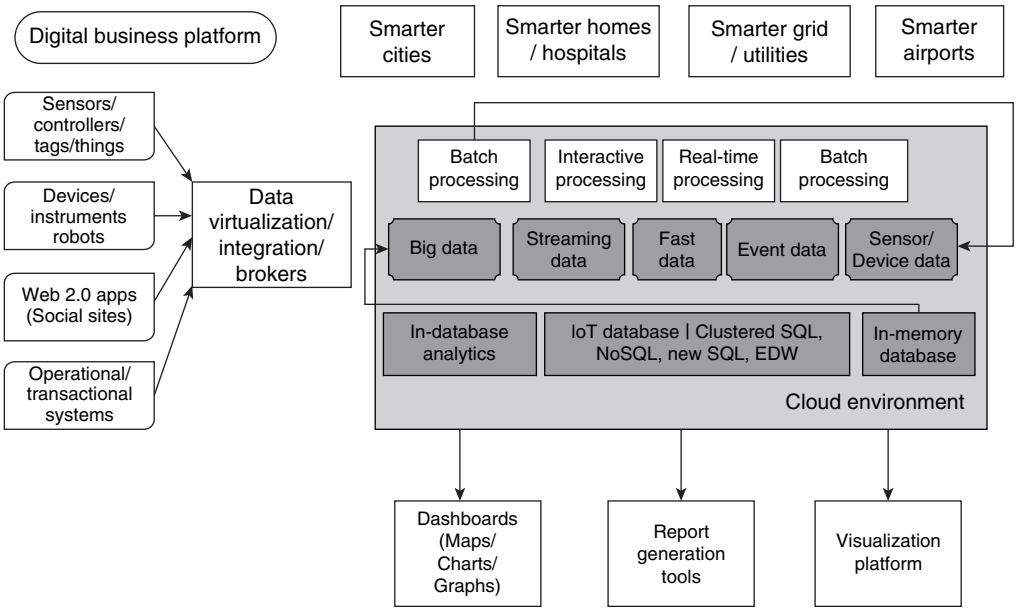
The Promising Digital Intelligence Methods

We are heading toward the era of zettabytes of digital data. Now it becomes mandatory to apply potential intelligence methods to make sense out of the exponentially growing data. There are new databases, file systems, platforms, algorithms, analytics methods, dashboards, other visualization solutions, message queues, event sources, streams, etc., for quickly and easily squeezing out actionable insights. The following list enumerates the key contributors:

1) Analytics methods of digital data (big, fast, and streaming data) for diagnostic and deterministic insights.
2) Machine and deep learning algorithms toward predictive, prescriptive, and personalized insights.
3) There are powerful data storage solutions such as SQL, NoSQL, and NewSQL databases, data warehouses, and lakes for digital data analytics.
4) There are in-memory databases for real-time analytics and actuation.
5) There are data virtualization and knowledge visualization tools, platforms, dashboards, etc.
6) There are data processing and analytics platforms (Spark, Storm, Samza, Flink, etc.) in cloud environments.
7) There are event stores such as Kafka for processing and stocking millions of event messages per second.
8) There are machine and deep learning platforms, frameworks, and libraries for accelerating and automating analytics (cognitive analytics).
9) Fog or edge data analytics is gaining speed with a number of lightweight platform solutions capable of running on fog/edge device clouds.

Here is a macro-level diagram depicting how applications across industry verticals systematically make use of data emanating from multiple sources to be smarter in their actions and

reactions. Data analytics platforms and machine learning toolkits on cloud infrastructures contribute enormously to capturing, cleansing, and crunching data to discover and disseminate knowledge. Applications and actuating systems, on getting appropriate insights, exhibit a kind of adaptive and adroit behavior in their delivery. With the process of moving from data to information and knowledge maturing fast along with the implementation technologies, data-driven insights, and insights-driven decisions will become the new normal for every institution, individual, and innovator.



Thus, there are three game changers. Collecting every bit of data, deriving actionable insights out of data volumes, and using the knowledge discovered in a timely and appropriate manner are being touted as the prime factors toward the projected knowledge society.

The Technological Approaches Toward Smarter Environments

Our environments are slowly yet steadily stuffed with IoT devices. Any IoT environment typically comprises scores of networked, resource-constrained as well as intensive and embedded systems. However, IoT artifacts are not individually intelligent. The charter is to make them intelligent individually as well as collectively. Experts have come out with a number of steps to be taken to have intelligent IoT devices. When we have intelligent IoT devices, the environment altogether is bound to be intelligent. All the occupants and owners of the environment will get a variety of people-centric, situation-aware, and knowledge-filled services. People will be hugely assisted by IoT devices in their everyday tasks. Multiple devices gel well in order to bring forth context-aware, insight-driven, and sophisticated services. As digitized entities and connected devices are being continuously empowered by remotely held software packages, data sources, event streams, and knowledge repositories, we can easily anticipate new categories of ground-breaking use cases and applications. In this section, we are to list the prominent and widely accepted ways for empowering our physical, mechanical, electrical, and electronics systems to be cognitive.

1) The **Internet of Agents (IoA)** for empowering each digital object to be adaptive, articulate, reactive, and cognitive through mapping a software agent for each of the participating digital objects.
2) Through realizing **Digital Services** (every digital object and connected device is expressed and exposed as a service) and through service orchestration and choreography, business-critical, process-optimized, and situation-aware digital applications can be crafted instantaneously and enhanced accordingly.
3) The emerging concept of **Digital Twin/Virtual Object Representation** is also maturing and stabilizing fast. Many industrial sectors are keenly evaluating and embracing this new paradigm.
4) With the excellent platform support, the proven and potential **IoT Data Analytics at Edge and Cloud Levels** is the way forward for knowledge discovery and dissemination.
5) The application of **Artificial Intelligence (AI)** technologies (data mining, statistical computing, machine and deep learning algorithms, computer vision, NLP, video processing, etc.) leads to the realization of smarter systems, services, and solutions.
6) The new concepts of **Decentralized Applications** and **Smart Contracts** being popularized through the blockbuster blockchain technology lead to scores of smart and safe applications.

Thus, the connectivity facility being provided by the IoT concept, the cognition capability through the AI algorithms, and the security features being realized through the application of the blockchain technology are being pronounced as the key technological paradigms for the future of IT and the society. With intelligent environments abound around us, we will get a number of noteworthy and trustworthy services. We will tend toward the digital universe, which brings in a growing array of premium and pioneering competencies for everyone.

Briefing the Brewing Idea of Digital Twin

All kinds of devices in our everyday environments are gradually getting integrated with cyber applications deployed in cloud environments to reap distinct benefits. That is, every physical, mechanical, electrical, or electronic system is being accordingly empowered in order to establish and sustain a seamless and spontaneous integration with faraway cloud applications. This technologically inspired linkage brings in a lot of fresh advantages. For example, manufacturing companies tie their machines on the manufacturing floor with one another as well as with enterprise-scale cloud-hosted applications such as SAP, the leading ERP solution, in order to automate several aspects. We call such enabled systems CPSs. This is becoming common nowadays. The phenomena of the IoD and the IoT came around and started to flourish.

Now there is a twist. Increasingly a virtual/logical/digital/cyber version [7] of any physical machine is being created and deposited in cloud environments to be made available online and in an on-demand fashion. The digital version is blessed with all the features and functionalities of the physical machine. With the cloud idea becoming a core technology, its adoption rate has multiplied in the recent past. There are software-defined and even edge clouds being formed with the latest technologies and tools in order to host and manage cyber applications. Due to their affordability, agility, and availability, the digital versions of physical entities are being made and kept in cloud environments. The physical and digital versions are integrated in order to be constantly in touch to communicate the real-time and runtime data of physical machines.

Besides digital versions, all kinds of historical data, enterprise-class applications, integrated data analytics platforms, machine and deep learning algorithms, etc., are being stocked in distributed

cloud environments. Thus, comprehensive analytics is easily accomplished. The data flowing from physical machines into their virtual versions enables real-time data analytics. Such a linkage enables architects, product engineers, and original equipment manufacturers (OEMs) in multiple ways. Before producing a machine physically, all its risks and opportunities can be identified and analyzed fully. How the various system components interact, what are the possible implications, etc., can be proactively and pre-emptively understood, and this knowledge helps designers come out with competent solutions. Such a scenario is going to be a game changer for multiple industry verticals.

Envisioning the Digital Universe

The digitization process has gripped the whole world today as never before and its impacts and the associated initiatives are being widely talked about. With an increasing variety of input and output (I/O) devices and newer data sources, the realm of data generation has gone up remarkably. It is forecasted that there will be billions of everyday devices getting connected, capable of generating an enormous amount of data assets, which need to be processed. It is clear that the envisaged digital world is to result in a huge amount of bankable data. This growing data richness, diversity, velocity, viscosity, virtuosity, value, and reach decisively activated business organizations and national governments. Thus, there is a fast spreading of newer terminologies such as digital enterprises and the economy. Now it is fascinating the whole world and this new world order has tellingly woken up worldwide professionals and professors to formulate and firm up flexible and futuristic strategies toward digitally transformed business, hotels, retail stores, healthcare, agriculture, manufacturing, etc. There are product vendors, service organizations, research labs, independent software vendors (ISVs), system integrators, consulting companies, etc., are formulating viable technologies, tools, platforms, and infrastructures to tackle this colossal yet cognitive challenge head-on. Also, cloud service providers are setting up software-defined compute, networking, and storage facilities. Newer types of databases, distributed file systems, data warehouses, data lakes, etc., are being realized to stock up the growing volume of business, personal, machine, people, and online data. These data storage solutions ultimately enable specific types of data processing, mining, and analyzing the data getting collected. This pivotal phenomenon has become a clear reason for envisioning the digital universe.

There will be a litany of hitherto unforeseen applications being built and deployed to empower people to experience the digital universe in which all kinds of data producers, middleware, and preprocessing systems, transactional and operational databases, analytical systems, virtualization and visualization tools, and software applications will be meaningfully connected with one another. Especially, there is a series of renowned and radical transformations in the sensor space. Nanotechnology and other miniaturization technologies have brought legendary changes in sensor design. The nano-sensors can be used to detect vibrations, motion, sound, color, light, humidity, chemical composition and many other characteristics of their deployed environments. These sensors can revolutionize the search for new oil reservoirs, structural integrity for buildings and bridges, merchandise tracking and authentication, food and water safety, energy use and optimization, healthcare monitoring and cost savings, and climate and environmental monitoring. The point to be noted here is the volume of real-time data being emitted by the army of sensors and actuators is exponentially growing and with the help of real-time analytics platforms and algorithms, real-time insights get squeezed out and supplied to actuating devices and people to ponder about and execute right countermeasures in time.

The steady growth of sensor networks increases the need for one million times more storage and processing power by 2020. It is projected that there will be one trillion sensors by 2025 and every single person will be assisted by approximately 150 sensors on this planet. Cisco has predicted that there will be 50 billion connected devices in 2020 and hence the days of the Internet of Everything (IoE) are not too far off. All these scary statistics convey one thing. That is, IT applications, services, platforms, and infrastructures need to be substantially and smartly invigorated to meet up all sorts of business and peoples' needs in the ensuing era of deepened digitization.

Precisely speaking, the data volume is going to be humongous as the digitization prospect is growing deep and wide. The resulting digitization-induced digital universe and economy will, therefore, be at war with the amount of data being collected and analyzed. The data complexity through the data heterogeneity and multiplicity will be a real challenge and concern for enterprise IT teams. That is, as accentuated earlier, the real-time analytics of big data is to lead to a series of disruptions and transformations.

Cloud-Native Applications (CNAs)

Thus far, we have discussed various transformative developments in the IT space, digital data, processes, services, applications, platforms, analytics, and environments [8]. Especially with the surging popularity of MSA, Kubernetes-managed containerized cloud environments, DevOps toolkits, and reliability engineering frameworks, producing and improving highly scalable and continuously available, portable, interoperable, extensible, and easily manageable applications are hugely simplified. Also, with these advancements, the aspect of accelerated software engineering sees the reality. The goal of cloud-agnostic application engineering and execution is also facilitated here. Such futuristic and flexible applications are termed cloud-native applications, which can run on private clouds locally as well as on public clouds remotely. Also, with the widespread focus on setting up edge device clouds, cloud-native services and applications can run on edge devices without any twist or tweak. We have allocated a special chapter on the title "Cloud-native Edge Computing" in this book. Also, a separate chapter for exquisitely explaining the distinct characteristics of cloud-native applications is incorporated in this book in order to clearly convey the nuances and nitty-gritty of cloud-native computing.

Conclusion

Digital transformation is the buzzword these days. It is believed that real digital transformation results in the much-needed business transformation. Customer experience is to go up. There will be fresh avenues to be explored to raise revenues. The enterprise assets' productivity is bound to rise. Premium offerings can be realized and delivered quickly. Business sentiments, technology changes, and users' expectations can be swiftly accommodated. Data-driven insights and insights-driven decisions and actions will become the new normal. Deeper and decisive automation can be accomplished through the participation of digital decisions. Real-time digital life applications can be built and released through edge computing. Digital data acquires special significance in the digital era. There will be a mix and match of digital and physical worlds. Context-aware physical services will be delivered to people in need. Thus, the possibilities and opportunities are literally limitless when digital data gets methodically converted into digital intelligence in association with state-of-the-art digital technologies, platforms, and infrastructures. The emergence of cloud-native computing is seen as a grand stimulator for the ensuing digital era.

References

1 What is cybersecurity? https://www.cisco.com/c/en_in/products/security/what-is-cybersecurity.html.
2 Everything you need to know about 5G. https://www.qualcomm.com/5g/what-is-5g
3 Describing the microservices architecture style. https://docs.microsoft.com/en-us/azure/architecture/guide/architecture-styles/microservices.
4 Top 10 Digital Transformation Technologies for 2021. https://mindsterdx.com/blog/digital-transformation-technologies/
5 What is an event-driven architecture? – Decoupled systems that run in response to events. https://aws.amazon.com/event-driven-architecture/
6 What is edge computing? https://www.redhat.com/en/topics/edge-computing/what-is-edge-computing
7 How does a digital twin work? https://www.ibm.com/topics/what-is-a-digital-twin
8 What is cloud native and what are cloud native applications? https://tanzu.vmware.com/cloud-native.