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The Revolutionary Paradigm of Enterprise Applications through the Lens of Data and Technology

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Abstract Innovation is disruptive, all of this influences the way we communicate, it streamlines the way we do business and also socializes our way of interacting with people and it is much more connected these days than it has ever been. Throughout the last century, it has taken numerous shapes and sizes, for example: being able to run the entire business on the very first large mainframe computer to finding ways to connect using the client server architecture, as well as from emergence of personal computers to contemporary-day most advanced digital business models, influencing pretty much every division of the economy essentially supporting individuals and organizations to maximize their brand recognition on the value chain. Anymore these days, with such an overwhelming majority of people, processes and intelligent product lines getting completely connected to the Internet, an enormous amount of data is now being accumulated, attempting to make the last decades IT infrastructures and applications fundamentally outdated. Therefore, it creates a burgeoning stumbling block among business executives and IT managers across numerous organizations making them to remodel their enterprise IT strategies that will really sustain the ever-increasing market standards and as such organizations are making every effort pushing themselves to explore numbers of ways to meet such demands. Well into the age of the digital revolution, data is indeed the primary source of fuel for several organizations that already is pushing the horizons of most of the 21st century technologies. Furthermore, with a mission to serve customers in real time, it is quite valuable for businesses to always have greater visibility of their daily operations through accelerating data to insight procedures. In order to overcome all of these challenges, organizations really do need to optimize their enterprise landscape through implementing modern, technology solutions, for example: Edge Computing Platforms designed and built to run Artificial Intelligence and Machine Learning models that effectively facilitate the massive amount of data to be processed in real time at just the edge of the device where it has been generated. This introduces operations closer to the edge of a network, which really minimizes the physical distance and time the data needs to be moved between things (device, smart product or any enterprise application) and cloud storage that enables real-time sensing and improves decision making processes. This brings in enterprises to benefit actionable insights and, at the same time, tends to increase operational efficiency, minimize cost, bring in real-time intelligence and helps to reduce the response time to milliseconds, something that eventually generates a sustainable value proposition for the designed to operate business process, creating the right edge to make each and every decision instantaneously without relying heavily on cloud systems in order to get the instructions.

Keywords Edge Computing, Cloud Computing, Data Latency, Big Data, Internet of Things, Machine Learning, Data Centers, Artificial Intelligence, Digital Revolution, Data Scientists, Fog Computing, Autonomous Vehicles, Augmented Reality, 5G Network, Structured Data, Unstructured Data, Pokemon Go, Drones, Industrial Automation, Load Balancing, Security, Dynamic Routing, Mars Land Rover, Smart Refrigerator, Things, Things Layer, Intelligence Layer, Knowledge Layer

1. Technology and Data Explosion Evolution – Reality

The earliest use of *computers* [1] and the *Internet* [2] has occurred predominantly in governmental, educational and research institutions. It wasn't until the *1980's* [3] that this newly emergent technology was made available to the crowd in the form of desktop machines, operating systems and software. The idea of accessing the internet was really exciting, even if we didn't know exactly what to do with it. Many still remember the ancient days of dial - up ("*You've Got Mail* [4] ") with the coveted AOL CD, managing stacks of floppy disks of any shape, color and size, and eventual roll-outs of *CD, DVD, USB, External Hard Drives*, [5] and so on. We still recall that - in the *early days of the internet*, [6]

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we used to sit there and wait for the Internet pages to load, having to look for the web pages to respond in order to get the information needed. Our initial understanding of data was information that needed to be shared, stored, analyzed and printed.

As technology has improved, *computer systems* [7] have become progressively competent, reliable data storage, computational power, something that has enabled highly sophisticated possibilities to use it. Room-sized mainframe computers processed data into printable reports to help facilitate better organizational decision – making. The power of computation grew into more sophisticated methods, including the ability to use data to analyze itself. In other words, what derivative value does the stacking of data received by the *Mars Land Rover* [8] provide *NASA* [9] engineers tasked with addressing the viability of *interplanetary space travel*? [10] Data serves a more pedestrian purpose within our atmosphere. It helps us to order takeout's, post pictures on Instagram, sell services and products, and stay connected regardless of where we live. We've ended up relying completely on the internet, to the extent that this really consumes a much greater portion of our personal time than we imagined.

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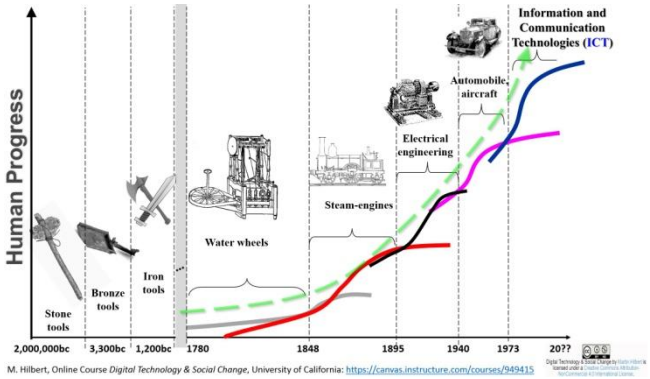

Figure 1. Technology Evolution [76]

The amount of data we produce every day is growing rapidly - over the last 2 years, *90 percent* [11] of the world's data has been generated. It is estimated that we produce around *2.5 exabytes* [12] of data each day *(2.5 exabytes = 2500 petabytes = 2.5 million terabytes = 2.5 Billion gigabytes)* - and continue to expand as videos, social media, online surfing and corporate data collection are expected to increase by 100 times by next year. Such expansion puts businesses under enormous pressure to respond more quickly to a global marketplace that not only generates *high volume data*, [13] but also expects to reap its *benefits* [14]. In view of what that data is expected to do, the traditional method of housing information in a static database is becoming less viable. Maintaining competitive edge is as much about keeping up with the 24/7 demands of businesses and consumers as it is about investing in solutions that will streamline operations.

Cloud computing [15] is technology's answer to the on-premise infrastructure dilemma, replacing costly hardware and software with the promise of making data more affordable and efficient when housed off-site. As a technology, Cloud computing creates a *paradigm shift*, [16] utilizing highly optimized virtual data centers where development platforms, servers, storage, software etc. are accessed online and remain online.

Sending all this generated data directly to the cloud and performing analytics on top of it creates limitations [17] relative to latency, bandwidth, security, and offline networks. Because these issues need to be resolved in order to make data securely available in real time, the IT industry has introduced an innovative solution known as "*Edge Computing*" [18] - the next generation of information management. EDGE computing can help organizations to overcome data latency, provide *real - time insights* [19] and lower operating costs by storing certain portions of critical data right on the "EDGE," making it a key component of the cloud infrastructure.

2. Accelerating Digital Business Models - Edge Computing

Edge Computing [18] is indeed a *high-performance* [20] distributed computing platform that allows the processing of data generated from connected devices and sensors at the source's "EDGE" for example: in which the data is produced. Instead of always transferring the data to the cloud, it processes the data on its own essentially becoming its own mini data center. Utilizing Edge Computing, organizations can process critical and sensitive *data in real time*, [21] through applying Artificial Intelligence (AI) techniques and machine learning algorithms that really can make perfect sense out of this information.

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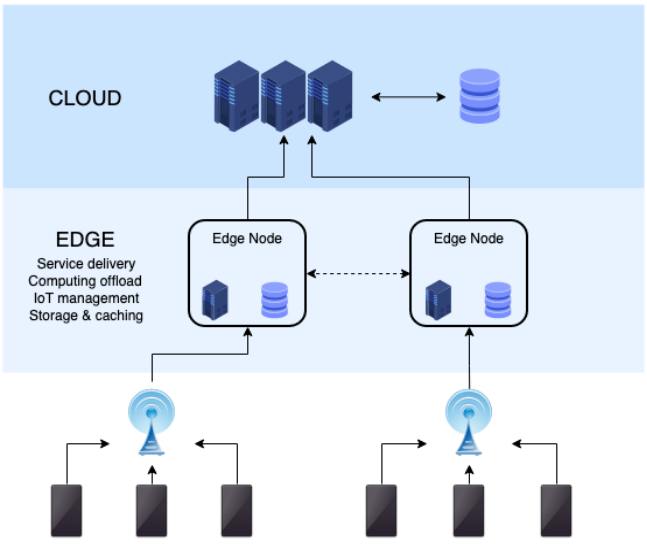

Figure 2. Edge Computing [77]

As you can see in today's *digital ecosystem*, [22] with the evolution of the *Internet of Things*, [23] billions of connected devices are producing data at such an explosive intensity, fretting the boundaries of cloud computing and infrastructures. In order to overcome these *challenges*, [17] infrastructure corporations and service providers are utilizing edge computing solutions to reduce some of the pressure from their existing centralized data centers. This '*at - the-source*' [21] technological advancement eliminates the ongoing problem of *load limitations* [17] for cloud infrastructures and network by transforming a data center to something like a source micro-hub or a network EDGE in order to accelerate computational and analytical capabilities. This whole ability to bypassing transmitting demands undoubtedly continues to drive *improved performance*, [24] quicker response time and much more innovation. On the consumer side, the perfect example would be a *smart refrigerator*, [25] which really informs you when it is out of milk.

As more of a technology, almost every micro unit of the *EDGE data center* [26] will have its own set of resources for computation, storage and network operations without the need of a stand-alone central location. This micro-platform will indeed be predominantly responsible for handling daily activities related specifically to:

- Networking
- Dynamic Routing
- Load Balancing
- Security
- Data Processing

There is already a common misperception that so many people happen to believe that Edge Computing is often used in the context of the Internet of Things (IoT) which is not true, whereas the EGDE infrastructure can indeed be leveraged across *any enterprise application* [27] or business sector that actually produces data as well as needs real-time information and insights in order to avoid latency. People are also more likely to believe that EDGE Computing is also the same thing as *Fog Computing*, [28] although both of these are different. Just like in Edge Computing where each and every device compute, stores, processes and analyzes receiving data from its own source of data making it a mini data center, whereas in fog computing, a specific centralized system processes the information from multiple network sources.

3. The Road to Innovation - Architecture

The *quintessential framework* [29] utilizing the EDGE Computing platform primarily consists of *three layers* [30].

- Things or Data Sources
- Intelligence or Information Layer
- Knowledge or Actionable Insights

Pertinently when divergent sources of information and things connect to the networks, they are referenced and known as the *Internet of Things* [31].

Things layer [32] makes a reference to each of the sources of information which generates data, whether it is the smart product, sensor systems, intelligent applications, machine logs, social media feeds, and so on. which mostly comprises of both *Structured* [33] and *Unstructured* [33] data.

The *intelligence layer* [34] is where most of the EGDE data centers undertake networking, information processing, computational as well as analytics activities much closer to the source of the data. Even though they better connected, Gateway will be the very first network device connected to the internet which can be as proximate as a few meters away or right at the data source. Furthermore, the very same gateway makes the decision on which data that it needs to send to the cloud and how much data it needs to process at the EDGE data centers, for example, business critical data processing related to operations, real-time sensor fusion and control processing may very well taking place at the EDGE, and therefore the data that could be processed at a latency that draws attention to long-term business intelligence would be sent to the cloud. *Data Scientists* [35] play a significant role nowadays in engineering the machine learning prototypes which will be further analyzed in and around the very large data sets readily accessible in the cloud. Later all of these intelligent designs will be implemented in and around the Edge data center in order to extract meaningful information from the real-time sources of data.

In Knowledge layer, valuable information generated from the machine learning models makes it possible for business executives take full *advantage* [36] of this knowledge and insight in order to make more informed decisions for the organization. This very same strategic approach opens up opportunities to transform customer loyalty programs, assimilate flight delay forecasts, perform complex medical

imaging research, and enforce fraud prevention algorithms. Through the use of Artificial Intelligence techniques, the substantial accessibility of cloud sources for secure data storage and the availability of cost-effective computational power makes it happen in transforming the entire businesses to create new smart applications which really deliver true *business value* [37] by

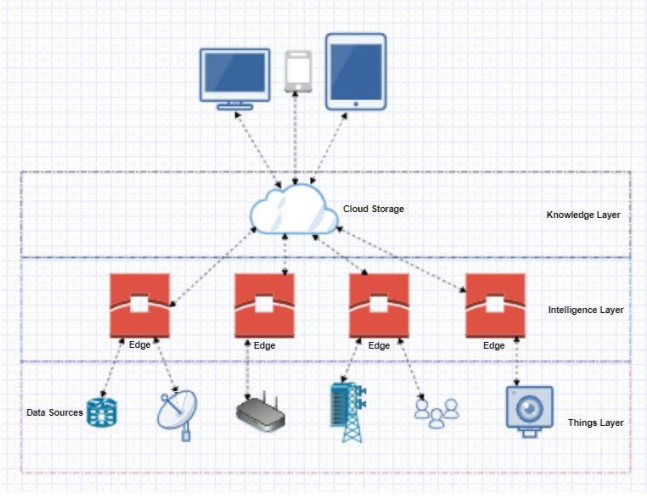

Figure 3. Edge Computing Architecture

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4. Enabling the Implementation – Benefits and Opportunities

Edge Computing is indeed the *next big thing* [38] where so many businesses are still in the early stages trying to figure out how they could overcome the *limitations* [17] of the classical cloud infrastructure architecture as well as find it hard to understand where they can really leverage the whole new paradigm to end up making the most out of their businesses.

While business momentum increases through instantaneous turnaround time becoming a crucial competitive edge for several industries edge computing will enable organizations *overcome data latency*, [39] generate real-time insights as well as lower production costs while processing certain segments of critical data right on the edge, attempting to make it a crucial component of cloud infrastructure.

Below are the major *benefits* [40] which EDGE computing can bring it to your business.

- **Real Time Intelligence**

Utilizing edge computing architecture, the large percentage of mission critical business data resides on the periphery where it has been generated and analyzed in real time. Intelligent devices connected to the Internet of Things and Cloud would have to make *accurate decisions* [41] in the blink of the eye despite having to wait for information to be obtained from cloud networks, because every single nanosecond of data latency will cost companies hundreds of thousands of dollars.

Edge Computing's very fundamental function would be to reduce network load and at the same time to have analytics tools right on the edge of the source of data, eliminating the *latency* [39] to move business critical data back and forth over the network for each and every transaction, bringing in quicker decision-making and measurable insights. This is really the fundamental principle under which *autonomous vehicles* [42] continuously communicate with the ginormous data flooding around them and make important *real-time driving decisions* [43] without having to depend on the responses from servers located in the cloud, because all the essential computation actually occurs in the EGDE.

- **Lower Operational Costs**

Utilizing Edge computing, enterprises can *reduce the amount of bandwidth* [44] they use between Things, Edge Data Centers and Cloud platforms. The raw data accumulated from data sources is therefore no longer required to move to cloud storage which ultimately results in reduced internet traffic and *costs associated* [45] with it. Companies would still get to choose, which key business services, information collected can be processed, analyzed at the edge, as well as which data could be sent to the cloud, resulting in a lower cloud-related infrastructure and maintenance costs which eventually avoid unnecessary workload and therefore increases the efficiency.

- **Scalability**

With the increasing percentage of connected devices trying to generate massive amounts of data, therefore it is always challenging for corporations to anticipate the need to provide IT infrastructure in order to ramp up their business operations as well as maximize the performance of the systems. EDGE Computational platforms *empower organizations* [46] to broaden their existing infrastructure footprint and computing capabilities. Furthermore, through the use of cloud-based solutions and EDGE computing frameworks, *businesses can transform* [47] its operations with EDGE data centers on a pre-integrated level with processing, storage, networking, energy and cooling resources explicitly capable of delivering any complicated business operations throughout different industry sectors.

All of these *Edge Data Centers* [48] can then be personalized to just about any capacity and could be deployed anywhere depending on your business operations, clearly outlined data regulations and policies of the organization.

• Security

Security, one of the primary cornerstones throughout all companies and perhaps the greatest dread about cloud computing is that it is not protected, something that makes more and more organizations to this day operate their businesses inside traditional databases to dodge cloud frameworks. EDGE technology tackles *security and compliance* [49] requirements for so many industries, particularly whereby data sources expose crucial sensitive personal information, health records as well as proximity monitoring related information, all of which can be collected, processed closer to the device through EDGE data centers rather than just to be sent. Then again, with all the overwhelming number of gadgets connected, the EDGE computing data centers become widely distributed, and there is also an incredible likelihood that some data centers can be breached, with either the intelligent gizmos becoming the *entry point* [50] for digital assaults.

It is critically important the safety of edge devices through *enforcing security procedures* [51]

- Licensed Authorized Access
- Network, Infrastructure and Equipment Security
- Encryption of software and data.
- Techniques for recuperation in case of emergency.

Keep in mind "*More Devices contributes to More Challenges*," IT *Security procedures* [52] should therefore handle which device can connect directly the network and in what environment. All these strategies should always be enforced across organizations to safeguard EDGE Data Centers in good enough condition to provide further protection to themselves and their customers in the long term.

5. Driving Business Value – Now and the Future

As we've already seen, sophisticated edge computing technology continues to power the storage, computation, intelligence and networking resources right at the edge of the data source. The number of companies incorporating EDGE platforms as part of their organization's *long-term strategy* [53] is increasingly rising day by day. By *2022*, [54] 75% of the data collected by companies will indeed be processed and analyzed outside of the cloud data centers.

There are several instances whereby edge computing could bring in tremendous value to a wide range of industries.

• Augmented Reality

It seems that we are still very much in the early stages to maximize the true potential of *Augmented Reality* [55]. Thanks to the Edge Computing and *5G network* [56] that happens to make AR diversified throughout sectors of the economy.

"*Augmented Reality is indeed the integration of digital information that superimposes graphics above that of the physical world*."

One prominent *Augmented Reality* [55] application scenario, which really captured everyone else's interest was "*Pokémon Go*," [57] something that made people a reason to race around it and catch Pokémon. It is indeed a game which always uses a GPS signal to detect your positioning and your smartphone screen to present *Pokémon* [57] into the world of reality. Therefore, depending on the location identified and the latitude and longitude coordinates recorded by that of the smartphones sensors in built, the application supplies the user with the relevant information which would then be *automatically superimposed* [58] using your mobile camera. As a result, the edge computing platform will accelerate the performance of numerous such AR applications through delivering highly analyzed important data relevant to the user's point of information, high computational power and storage capabilities right at the edge.

• Autonomous Vehicles

Autonomous Vehicles [42] are amongst the most complex applications which really utilize EDGE Computing, Artificial Intelligence techniques and machine learning algorithms, making millions of complex calculations each second through analyzing terabytes of data related to location and weather forecasts, at the v*ery same time communicating with several other vehicles on the road. Edge computing technology plays a very important role* [59] in guaranteeing how information is processed and communicated to many other vehicles in real-time by eliminating latency for the smooth and controlled operation of vehicles.

The automotive industry has already invested *billions of dollars* [60] in the whole of technology, and industry giants already are making a concerted effort in order to bring this self-driving vehicle a consumer reality before 2022.

• Drones

The use of artificial intelligence is already making our lives increasingly efficient by attempting to bring innovation to reality including such as *Drones* [61]. It is indeed a light aircraft without the need for a human pilot on board, generally built and run by remote control.

Envision about what it would be when you purchase your breakfast online and watch the drone deliver that order at your window [62]. Isn't really that amazing? Technological advances are at its highest quality. Today, real-time platforms may not empower drones to fly higher, however, instead lead them to improved access control which really encourages different businesses to allow using of drone fleets across large enterprise regions, making them "*the future of delivery*." [63]

Edge's computing framework tends to help in order to overcome the challenges involved with both the deployment

and optimization of drone fleets while performing out intelligence, processing, storage and networking operations right at the edge of drones, [64] because each edge node could really execute analytics, navigation, collaboration, signaling and control operations.

- **Industrial Automation**

Well into the world of industrial production after mechanization, electrification, and computerization, the Internet of Things has been at the heart and driving factor and today what we describe it as *Fourth Industrial Revolution* [65]. Throughout all these industrial revolutions, one thing that is absolutely common, seems to be that factory owners are almost always trying to find ways to improve productivity and greatly reduce costs, which ultimately resulted in technological advances to greatly benefit their business model.

Edge Computing offers a wide range of economic advantages to automation touch with reality applications as when the processing of real-time data accumulated from *machine sensors* [66] right on the edge could indeed lead to reduced maintenance costs, continued to improve the accuracy of the supply chain, regulated material production, increased demand, elevated operational efficiency and smoother response to service.

6. Edge Connectivity - Data Centers

The phrase EDGE makes a reference to IT infrastructure as well as data center facilities wherein the Internet of Things corresponds to smart products, sensors and information gathered from devices and observations extracted from them. We are very much in the early days of the *EDGE data center markets* [67] and perhaps the prototypes are still rapidly changing, however below are the three most prominent examples of data centers around the world currently available in the market.

- **Micro Data Center**

Micro Data Centers [68] are efficient and secured computing facilities each of which is seamlessly integrated and provide multipurpose IT solutions that include all of the power required, storage, security and corresponding maintenance resources within one unit. Micro Data Centers *empower businesses* [69] to take full advantage of the enterprise applications right at the edge of the device. A prime example of the Micro Data Center can be used in industrial automation [70] for system-to-machine information sharing.

- **Modular Data Center**

Modular Data Centers [71] are streamlined and scalable data centers all of which can be deployed anywhere around the world and are highly beneficial for medium and small-sized enterprise applications. Each modular data center is *infinitely scalable* [72] for rapid deployment, which can take up to a few weeks, and perhaps a good example of such a Modular data center can indeed be connected to the *utility Sub Station power grid* [73].

- **Portable Data Center**

Portable data centers [74] are primarily another type of mission critical data center commonly installed within 20, 40 or 50-feet container filled to the brim with network infrastructure which can be delivered utilizing standard shipping procedures. All such Portable Data Centers are generally weather resistant and fortified, several of which are *deployed in remote locations* [75] and can be used in a multitude of industrial sectors, including those of the government sector for emergency preparedness, the armed forces in war zones, and many more.

7. Conclusions

Organizations are taking positive steps to accomplish the mission of benefiting clients through outstanding services, and therefore are making each and every attempt to gain actionable insight by having to process data in real time by supplanting legacy networking systems with today's most advanced technology solutions. Doing so makes it easier them to eliminate network latency, lower operating costs, enhance interoperability and control access, making businesses to upscale in terms of market share and greatly increasing return on investment. Edge Computing has now become the latest major thing where more and more businesses are still in the early stages trying to figure out how they could overcome the constraints of traditional cloud technology architecture and find it hard to understand where they could utilize the whole new paradigm to make the most out of their businesses. Utilizing Artificial Intelligence approaches, the vast accessibility of cloud sources for data storage and cost-effective computational power makes the company to transform into Future-centric advanced computing platforms in order to create new smart applications that deliver sustainable business value.

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REFERENCES

[1] Computers | Timeline of Computer History | Computer History Museum. (n.d.). Retrieved from https://www.computerhistory.org/timeline/computers/.

[2] Brief History of the Internet. (2017, September 10). Retrieved from https://www.internetsociety.org/internet/history-internet/brief-history-internet/.

[3] Wikipedia contributors. (2020, January 11). History of the Internet. In *Wikipedia, The Free Encyclopedia*. Retrieved 22:21, January 13, 2020, from https://en.wikipedia.org/w/index.php?title=History_of_the_Internet&oldid=935258997.

[4] You've Got Mail and How AOL Brought Email to, Well? Everyone! (n.d.). Retrieved from https://radhistory.com/youve-got-mail-and-how-aol-brought-email-to-well-everyone.

[5] From floppy disks to flash drives, the history of storage. (2017, November 16). Retrieved from https://www.ciodive.com/news/from-floppy-disks-to-flash-drives-the-history-of-storage/511081/.

[6] Do you remember these internet scenarios from the 90s and early 00s? (2018, September 27). Retrieved from https://home.bt.com/tech-gadgets/internet/broadband/20-internet-scenarios-from-the-90s-and-early-00s-that-will-make-you-feel-oddly-nostalgic-11363974940240.

[7] A Timeline of How Computers Changed History and Business as We Know it. (n.d.). Retrieved from https://www.bookyourdata.com/email-list-database/computers-changed-history.

[8] Mars.nasa.gov. (2019, February 13). NASA's Opportunity Rover Mission on Mars Comes to End? NASA's Mars Exploration Program. Retrieved from https://mars.nasa.gov/news/8413/nasas-opportunity-rover-mission-on-mars-comes-to-end/.

[9] Wikipedia contributors. (2020, January 11). NASA. In *Wikipedia, The Free Encyclopedia*. Retrieved 00:32, January 14, 2020, from https://en.wikipedia.org/w/index.php?title=NASA&oldid=935294237.

[10] By Amanda Barnett. (n.d.). 10 Things: Going Interstellar? NASA Solar System Exploration. Retrieved from https://solarsystem.nasa.gov/news/881/10-things-going-interstellar/.

[11] Big Data, for better or worse: 90% of world's data generated over last two years. (2020, January 14). Retrieved from https://www.sciencedaily.com/releases/2013/05/130522085217.htm.

[12] How Much Data Is Generated Every Minute? [Infographic]. (2018, June 15). Retrieved from https://www.socialmediatoday.com/news/how-much-data-is-generated-every-minute-infographic-1/525692/.

[13] Big data: 3 biggest challenges for businesses. (2019, June 24). Retrieved from https://www.techrepublic.com/article/big-data-3-biggest-challenges-for-businesses/.

[14] Anurag. (n.d.). 5 Benefits: Competitive Advantages of Big Data in Business. Retrieved from https://www.newgenapps.com/blog/importance-benefits-competitive-advantage-big-data.

[15] Ranger, Steve. (2018, December 13). What Is Cloud Computing? Everything You Need To Know About The Cloud, Explained | ZDNet. ZDNet. Retrieved January 14, 2020, from https://www.zdnet.com/article/what-is-cloud-computing-everything-you-need-to-know-from-public-and-private-cloud-to-software-as-a/.

[16] Hardy, Quentin. (2018, February 8). How Cloud Computing Is Changing Management. Harvard Business Review. Retrieved January 14, 2020, from https://hbr.org/2018/02/how-cloud-computing-is-changing-management.

[17] Lavinski, sarah. (2019, April 4). 10 Disadvantages & Risks Of Cloud Computing. Medium. Retrieved January 14, 2020, from https://medium.com/faun/10-disadvantages-risks-of-cloud-computing-35111de75611.

[18] Ismail, Nick. (2018, April 20). Everything You Need To Know About Edge Computing. Information Age. Retrieved January 14, 2020, from https://www.information-age.com/everything-edge-computing-123471589/.

[19] Moore, Rick. (2019, February 5). Living On The Edge: What You Should Know About Edge Computing | Digital Realty. Digital Realty. Retrieved January 14, 2020, from https://www.digitalrealty.com/blog/living-on-the-edge-what-you-should-know-about-edge-networking.

[20] Shaw, Keith. (2019, November 13). What Is Edge Computing And Why It Matters. Network World. Retrieved January 14, 2020, from https://www.networkworld.com/article/3224893/what-is-edge-computing-and-how-it-s-changing-the-network.html.

[21] Waxer, Cindy. (2019, February 26). How Edge Computing Will Bring Business To The Next Level. Network World. Retrieved January 14, 2020, from https://www.networkworld.com/article/3342455/how-edge-computing-will-bring-business-to-the-next-level.html.

[22] Jacobides, Michael. G. Lang, Nickolaus. Louw, Nanne. Szczepanski, Konrad Von. (2019, June 26). What Does A Successful Digital Ecosystem Look Like? Https://www.bcg.com. Retrieved January 14, 2020, from https://www.bcg.com/publications/2019/what-does-successful-digital-ecosystem-look-like.aspx.

[23] Meola, Andrew. (2019, December 18). A Look At Examples Of IoT Devices And Their Business Applications In 2020. Business Insider. Retrieved January 14, 2020, from https://www.businessinsider.com/internet-of-things-devices-examples.

[24] Aleksandrova, Mary. (2019, February 1). The Impact Of Edge Computing On IoT: The Main Benefits And Real-Life Use Cases | Eastern Peak. Eastern Peak. Retrieved January 14, 2020, from https://easternpeak.com/blog/the-impact-of-edge-computing-on-iot-the-main-benefits-and-real-life-use-cases/.

[25] Baker, Justin. (2017, November 2). Edge Computing — The New Frontier Of The Web. https://hackernoon.com/. Retrieved January 14, 2020, from https://hackernoon.com/edge-computing-a-beginners-guide-8976b6886481.

[26] Waldhauser, Bela. (2019, November 7). The Edge & Edge Data Centers: Gaining Clarity. dot magazine. Retrieved January 15, 2020, from https://www.dotmagazine.online/issu

es/on-the-edge-building-the-foundations-for-the-future/edge-data-centers.

[27] Mclellan, Charles. (2018, October 1). Edge Computing: The State Of The Next IT Transformation | ZDNet. ZDNet. Retrieved January 15, 2020, from https://www.zdnet.com/article/edge-computing-the-state-of-the-next-it-transformation/.

[28] Ismail, Kaya. (2018, August 14). Edge Computing Vs. Fog Computing: What's The Difference? CMSWire.com. Retrieved January 15, 2020, fromhttps://www.cmswire.com/information-management/edge-computing-vs-fog-computing-whats-the-difference/.

[29] NTT SCL. (2016, June 14). Edge Computing Platform. YouTube. Retrieved January 15, 2020, from https://www.youtube.com/watch?v=RjMS15V_7nQ.

[30] MSV, Janaki. (2017, February 7). Edge Computing -- Redefining The Enterprise Infrastructure. Forbes. Retrieved January 15, 2020, from https://www.forbes.com/sites/janakirammsv/2017/02/07/edge-computing-redefining-the-enterprise-infrastructure/#7ada6c5a7549.

[31] Burgess, Matt. (2018, February 16). What Is The Internet Of Things? WIRED Explains. Wired. Retrieved January 15, 2020, from https://www.wired.co.uk/article/internet-of-things-what-is-explained-iot.

[32] Explaining Computers. (2019, October 20). Explaining Edge Computing. YouTube. Retrieved January 15, 2020, from https://www.youtube.com/watch?v=0idvaOCnF9E.

[33] (2019, January 9). Data Types: Structured Vs. Unstructured Data | Big Data Framework©. Big Data Framework©. Retrieved January 15, 2020, from https://www.bigdataframework.org/data-types-structured-vs-unstructured-data/.

[34] IBM Cloud. (2019, October 1). What Is Edge Computing? YouTube. Retrieved January 16, 2020, from https://www.youtube.com/watch?v=cEOUeItHDdo.

[35] Zola, Andrew. (n.d.). Why Edge Analytics Is The Future Of Data Science - Intersog. Intersog. Retrieved January 16, 2020, from https://intersog.com/blog/why-edge-analytics-is-the-future-of-data-science/.

[36] Forbes, Technology Council. (2019, December 23). 13 Ways Edge Computing Can Benefit Businesses. Forbes. Retrieved January 16, 2020, from https://www.forbes.com/sites/forbestechcouncil/2019/12/23/13-ways-edge-computing-can-benefit-businesses/#3af1aa9239a8.

[37] Sarkar, Sampriti. (2017, November 30). How Edge Computing Will Transform Businesses | Analytics Insight. Analytics Insight. Retrieved January 16, 2020, from https://www.analyticsinsight.net/how-edge-computing-will-transform-businesses/.

[38] Jennings, Ralph. (2018, May 31). Edge Computing Emerges As The Next Big Thing In Tech, And Taiwan Will Help Power It. Forbes. Retrieved January 16, 2020, from https://www.forbes.com/sites/ralphjennings/2018/05/31/the-next-big-thing-in-asian-tech-is-edge-computing/#327f52ae6802.

[39] Nelson, Patrick. (2017, August 7). No-latency Edge Computing Will Snowball. Network World. Retrieved January 16, 2020, from https://www.networkworld.com/article/3213204/no-latency-edge-computing-will-snowball.html.

[40] Nasser, Mohamad. (2016, November 10). Four Advantages Of Edge Computing - Sprint Business. Sprint Business. Retrieved January 16, 2020, from https://business.sprint.com/blog/four-advantages-edge-computing/.

[41] Solutions, eBbiz. (2019, February 12). What Is Edge Computing? | Moving Intelligence To The Edge. EBiz Solutions, LLC. Retrieved January 16, 2020, from https://www.thinkebiz.net/what-edge-computing/.

[42] Boguda, SatishKumar. Arsid Shailaja (2019, April). Autonomous Cars – Predicting Future Customers. IRJET. Retrieved January 16, 2020, from https://www.irjet.net/archives/V6/i4/IRJET-V6I41176.pdf.

[43] Petrucelli, John. (2018, December 13). Edge Computing And How It Impacts Autonomous Vehicles. Motus | Mobile Workforce Solutions. Retrieved January 16, 2020, from https://www.motus.com/edge-computing-and-autonomous-vehicles/.

[44] CIO Outlook, Apac. (2019, November 6). Edge Computing: Technology To Reduce Bandwidth. Retrieved January 16, 2020, fromhttps://www.apacciooutlook.com/news/edge-computing-technology-to-reduce-bandwidth-nwid-4998.html.

[45] Investment, Vietnam., & VIR, -. (2018, September 24). Reducing Expenses With Edge Computing. Vietnam Investment Review - VIR. Retrieved January 16, 2020, from https://www.vir.com.vn/reducing-expenses-with-edge-computing-62602.html.

[46] Carroll, Ken. Mahesh, Chandramouli. (2019, June 20). Scaling IoT To Meet Enterprise Needs. Deloitte Insights. Retrieved January 16, 2020, from https://www2.deloitte.com/us/en/insights/focus/internet-of-things/enterprise-iot-solutions-edge-computing-cloud.html.

[47] Chokshi, Rupesh. (n.d.). Transforming Your Business At The Network Edge. AT&T. Retrieved January 16, 2020, from https://www.business.att.com/learn/top-voices/transforming-your-business-at-the-network-edge.html.

[48] Waxer, C. (2019a, March 19). Deploying Highly Secure, Easy To Deploy And Cost-effective Micro Data Centers. Network World. Retrieved January 16, 2020, from https://www.networkworld.com/article/3373839/deploying-highly-secure-easy-to-deploy-and-cost-effective-micro-data-centers.html.

[49] Role, T., computing, edge, & security, computing. (2019, June 18). The Role Of Edge Computing Security In Enterprise Networks. Search Networking. Retrieved January 16, 2020, fromhttps://searchnetworking.techtarget.com/tip/The-role-of-edge-computing-security-in-enterprise-networks.

[50] Jpalmer, danny. (2018, October 1). Edge Computing: The Cybersecurity Risks You Must Consider | ZDNet. ZDNet. Retrieved January 16, 2020, from https://www.zdnet.com/article/edge-computing-the-cyber-security-risks-you-must-consider/.

[51] Brown, Steven. (2019, October 31). How To Prevent Edge Computing Security Risks In A Connected World. Schneider Electric Blog. Retrieved January 16, 2020, from https://blog.se.com/datacenter/dcim/2019/10/31/how-to-prevent-edge-computing-security-risks-connected-world/.

[52] Edwards, John. (2018, January 21). Edge Computing Security Dos And Don'ts. Network Computing. Retrieved January 16,

2020, from https://www.networkcomputing.com/network-security/edge-computing-security-dos-and-donts.

[53] Sinnarkar, Makarand. Bhushan, Jagtap. Supradip, Baul. (2019, May). Edge Computing Market Size, Share & Trends | Industry Forecast - 2025. Allied Market Research. Retrieved January 17, 2020, from https://www.alliedmarketresearch.com/edge-computing-market.

[54] Trifiro, Matt. Smith, Jacob. (2019). State of the Edge. Seagate. Retrieved January 17, 2020, from https://www.seagate.com/www-content/enterprise-storage/it-4-0/images/Data-At-The-Edge-UP1.pdf.

[55] Wikipedia contributors. (2020, January 15). Augmented reality. In Wikipedia, The Free Encyclopedia. Retrieved 19:15, January 17, 2020, from https://en.wikipedia.org/w/index.php?title=Augmented_reality&oldid=935894183.

[56] Wikipedia contributors. (2020, January 17). 5G. In Wikipedia, The Free Encyclopedia. Retrieved 19:17, January 17, 2020, from https://en.wikipedia.org/w/index.php?title=5G&oldid=936262923.

[57] Wikipedia contributors. (2020, January 12). Pokémon Go. In Wikipedia, The Free Encyclopedia. Retrieved 19:19, January 17, 2020, from https://en.wikipedia.org/w/index.php?title=Pok%C3%A9mon_Go&oldid=935384822.

[58] Warner, Claire. (2016, July 13). This Is How "Pokemon Go" Actually Works. Bustle. Retrieved January 17, 2020, from https://www.bustle.com/articles/172317-how-does-pokemon-go-work-heres-everything-we-know-about-the-tech-behind-the-augmented-reality.

[59] Eliot, Lance. (2019, June 9). Edge Computing Is Big Booster For Autonomous Self-Driving Cars. Medium. Retrieved January 17, 2020, from https://medium.com/@lance.eliot/edge-computing-is-big-booster-for-autonomous-self-driving-cars-c36537fcef5f.

[60] Kokalitcheva, Kia. (2018, October 27). Self-driving Technology Has Attracted A Staggering Amount Of Investment. Axios. Retrieved January 17, 2020, from https://www.axios.com/autonomous-vehicles-technology-investment-7a6b40d3-c4d2-47dc-98e2-89f3120c6d40.html.

[61] Wikipedia contributors. (2020, January 13). Drone. In Wikipedia, The Free Encyclopedia. Retrieved 19:38, January 17, 2020, from https://en.wikipedia.org/w/index.php?title=Drone&oldid=935525114.

[62] Kelso, Alicia. (2019, July 12). Food Delivery Via Drones May Be Closer Than You Think. Forbes. Retrieved January 17, 2020, from https://www.forbes.com/sites/aliciakelso/2019/07/12/food-delivery-via-drones-may-be-closer-than-you-think/#294cb6974385.

[63] Kumar, Ayush. (2019, September 3). Drone Delivery - Future Of Shipping Industry. Circuit Digest. Retrieved January 17, 2020, from https://circuitdigest.com/article/drone-delivery-future-of-shipping-industry.

[64] Guttman, Chase. (2019, August 17). Drone Innovation Turns to Edge Computing. Nutanix. Retrieved January 17, 2020, from https://www.nutanix.com/theforecastbynutanix/technology/drone-innovation-turns-to-edge-computing.

[65] Satish Kumar Boguda , Arsid Shailaja, 2019, The Future of Customer Experience in the Information Age of Artificial Intelligence – Get Ready for Change, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) Volume 08, Issue 06 (June 2019), DOI : http://dx.doi.org/10.17577/IJERTV8IS060622.

[66] Resnick, Craig. (2018, October 23). Edge Computing In Industrial Environments | ARC Advisory Group. ARC Advisory Group. Retrieved January 17, 2020, from https://www.arcweb.com/blog/edge-computing-industrial-environments.

[67] Sverdlik, Yevgeniy. (2015, August 26). How Edge Data Center Providers Are Changing The Internet's Geography. Data Center Knowledge. Retrieved January 17, 2020, from https://www.datacenterknowledge.com/archives/2015/08/26/how-edge-data-center-providers-are-changing-the-internets-geography.

[68] (n.d.). Micro Data Center - DELTA. Delta Power Solutions. Retrieved January 17, 2020, from https://www.deltapowersolutions.com/en/mcis/data-center-solutions-micro-datacenter.php.

[69] O'Donnell, Lindsey. (2017, November 30). Life On The Edge: Why Micro Data Centers Are The Next Frontier. CRN. Retrieved January 17, 2020, from https://www.crn.com/news/data-center/300096141/life-on-the-edge-why-micro-data-centers-are-the-next-frontier.htm.

[70] Attom. (2019a). Micro Data Center – The Future Ready Choice for Modern Enterprise IT. ATTOM. Retrieved January 17, 2020, from https://attom.tech/wp-content/uploads/2019/08/Industry-Application-Guide-Micro-Data-Center-the-Future-Ready-Choice-for-Enterprise-IT-Attom-Technology.pdf.

[71] (2020). Modular Data Center - BASELAYER. BASELAYER. Retrieved January 17, 2020, from https://www.baselayer.com/products/modular-data-center/.

[72] (2019c). IBM Prefabricated Modular Data Center - Overview - United States. IBM. Retrieved January 17, 2020, from https://www.ibm.com/us-en/marketplace/prefabricated-modular-data-center.

[73] Miller, Rich. (2015, June 23). Plugging Into The Fast Lane Of The Grid. Data Center Frontier. Retrieved January 17, 2020, from https://datacenterfrontier.com/plugging-into-the-fast-lane-of-the-grid/.

[74] Miller, Rich. (2007, October 9). Google Patents Portable Data Centers. Data Center Knowledge. Retrieved January 17, 2020, fromhttps://www.datacenterknowledge.com/archives/2007/10/09/google-patents-portable-data-centers.

[75] Wall Street Journal. (2015, March 9). The Portable Data Center That Fits In A Suitcase. YouTube. Retrieved January 17, 2020, from https://www.youtube.com/watch?v=HkQl8mo2GWA.

[76] File:Long Waves of Social Evolution.jpg. (2017, December 27). Wikimedia Commons, the free media repository. Retrieved 00:42, January 15, 2020 from https://commons.wikimedia.org/w/index.php?title=File:Long_Waves_of_Social_Evolution.jpg&oldid=274670627.

[77] File:Edge computing infrastructure.png. (2019, September 10). Wikimedia Commons, the free media repository. Retrieved 00:57, January 15, 2020 from https://commons.wikimedia.org/w/index.php?title=File:Edge_computing_infrastructure.png&oldid=365296364.