The Future of Edge Computing

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What is Edge Computing?

The digital cloud was first brought into the mainstream a few years ago, and after some initial confusion about what exactly it was, it has been extremely popular with the vast majority of tech users. It enabled information to be stored and processed on remote servers, which meant our devices could offer services beyond their technical capabilities. Using the cloud, a device with only a few gigabytes of memory can effectively host an infinite amount of data. As time has gone by, though, the cloud has started to impede certain technologies, especially IoT.

The Internet of Things is simply too broad and large in scale for a cloud service to be a practical means of computer processing. The data being sent by an IoT system over wifi or cellular would slow down the entire network. Not only that, but IoT devices aren't guaranteed to always be within range of an internet connection. This means that without access to the central cloud, devices could be effectively useless.

This is where edge computing comes in. Rather than removing data storage and processing from devices, edge computing pushes the data closer to them, improving cost and performance and making the devices more independent. This doesn't completely eliminate the need for a cloud, but it can reduce the amount of data that needs to be sent to the cloud. Edge computing allows for cloud-like functionality on our own devices or at the network "edge," which is a term used to describe the point where a device or network communicates with the internet.

That could be a device's processor, a router, an ISP, or a local edge server. Instead of sending data to a remote server, data is processed as close to the device as possible or even on the device itself.

For example, say you have an autonomous car with a rearview camera used for accident prevention. Relying on a cloud computing system to process the image data and return results to the onboard systems for action would be impractical since the slow/intermittent data connection would result in poor performance. This setup would also use a lot of data for transferring large video files back and forth from the cloud, and it would strain the cloud server to process data from several cameras at once and send back critical results almost instantaneously. But if the car's computing system can perform most of the process itself and send information to the cloud only when truly necessary, it results in faster and more reliable performance, lower costs for data transfer, and less strain put on cloud servers.

This is the basic idea behind the concepts of edge computing. In this paper, we will explore in greater detail the concepts and benefits of edge computing and share a variety of insights about its future.

The Current State of the Industry

Technology has swung between centralized and decentralized computing several times in the past. For example, the IBM 360, like other early computer models, was a centralized computing unit that performed all of its operations within a closed system. Compare that to current PCs and you can see that the new computers perform many more decentralized actions, sending and receiving data that is processed on countless remote servers. The cloud is an example of a shift back towards centralized computing. A cloud server is the central computing unit where data from many other machines is stored or processed. But at the same time, we're moving towards decentralization with blockchain technology, which eliminates a central authority for processing transactions and instead divides the work among many machines.

Edge computing marks another shift towards decentralization, and its usefulness is apparent when you look at the emerging IoT industry. Moving the countless processes that an IoT system is constantly performing away from a centralized cloud and onto the peripheral devices offloads the strain on the central servers, keeping an IoT project fast and agile in spite of its size.

Edge computing is also important to IoT because IoT devices aren't always connected to the internet. IoT connectivity solutions are still in their early stages and therefore may not be completely reliable for most at-scale IoT projects. So keeping the computing on or closer to the devices themselves rather than having each device rely on a remote server means that devices can still perform their functions when outside of connectivity. Companies like Microsoft, Amazon, Google, Dell, IBM, and Cisco are all working on edge computing development.

Amazon's Three Laws Of IoT

Amazon, one of the leaders in edge computing, has laid out **three basic laws** that it uses to guide its edge computing and IoT development.[1]

1. The Law of Physics. The first law of IoT is the idea that physical limitations have to be considered during an IoT project's development, and not just the technological or digital limits. Going back to the autonomous vehicle example used earlier, there is a real, physical need for the data to be processed locally on the vehicle. Even though the processes can be sent to a cloud to be processed, the Law of Physics determines that local processing is the correct answer.

2. The Law of Economics. The second law takes financial feasibility into account. For most companies - if not all - IoT systems are an extreme financial undertaking. One of the most significant costs is that of keeping everything connected through a service provider. The less data devices are sending over a network, the more financially viable an IoT project will be.

3. The Law of the Land. Lastly, the third law refers to the regional laws that an IoT project has to abide by. This could be literal laws - GDPR, for example - or simply limitations of a region's infrastructure.

Considering these laws while looking at IoT and edge computing possibilities will help keep us grounded and realistic about the world of edge computing.

Key Stats

- According to Gartner, the number of IoT devices will increase from **30 billion to 50 billion by 2020**, concurrently increasing the demand for edge computing[2]

- Between 2017 and 2025, the global market for edge computing analytics is **expected to grow with a CAGR of 27.6%**[3]

- Hybrid Cloud Solutions predicts that **5.6 billion IoT devices** will rely on edge computing for data collection and processing in 2020[4]

- Today, 10% of enterprise-generated data is created and processed through edge computing; Gartner predicts that by 2022 that number **will reach 50%**[5]

- The mobile edge computing market is predicted to grow **from $185.8 million in 2017 to $838.6 million in 2022**, with a CAGR of 35.2%[6]

- In 2020, **18% of the money** that IT departments invest into IoT will be towards edge computing infrastructure[7]

- By 2022, the global edge computing market will be **valued at $6.72 billion**, at a CAGR of 35.4%[8]

- The US edge computing market is expected to grow at a CAGR of 10.3% between now and 2022, with a value of **$5,696.6 million by 2022**[9]

- **70% of CEOs** are aware of edge computing and have edge computing initiatives within their organization[10]

- **40% of CEOs** increased their edge computing budget in 2018, and 75% expect more research grant funding opportunities[11]

- The majority of CEOs say that edge computing **falls under R&D**, followed by new ventures[12]

- IoT is the primary market for edge computing, **accounting for 70%** of the edge computing industry[13]

- Most organizations that are reluctant to adopt edge computing say that **security and uncertainty** are the two major factors for their reluctance[14]

- Most of the interest in edge computing for businesses stems from **latency and network bandwidth improvements**[15]

- The top three industries looking to adopt edge computing are **smart cities, manufacturing, and transportation**[16]

- According to a survey by SWIM, **60% of senior management** can see strategic value in data in motion[17]

- The SWIM study also found that in a sample of IoT devices, **65% of the data being sent to the cloud was at least five days old**, suggesting that the data processing is more important than uploading[18]

Key Players

Amazon

Amazon has been at the forefront of IoT technology for some time now, with their most significant offering to the industry being Amazon Web Services (AWS). AWS is a collection of services that users can take advantage of to develop their projects and systems. This helps businesses and indie developers get a jump start on their projects. **AWS IoT Greengrass** is a service offered through AWS that is specifically made for IoT edge computing use cases.[19] This service extends the capabilities of the cloud onto the IoT devices within a particular network, allowing them to perform the work that the cloud would normally do. These devices connect to local networks, communicating with one another, and only communicate with the cloud when necessary and possible.

Microsoft

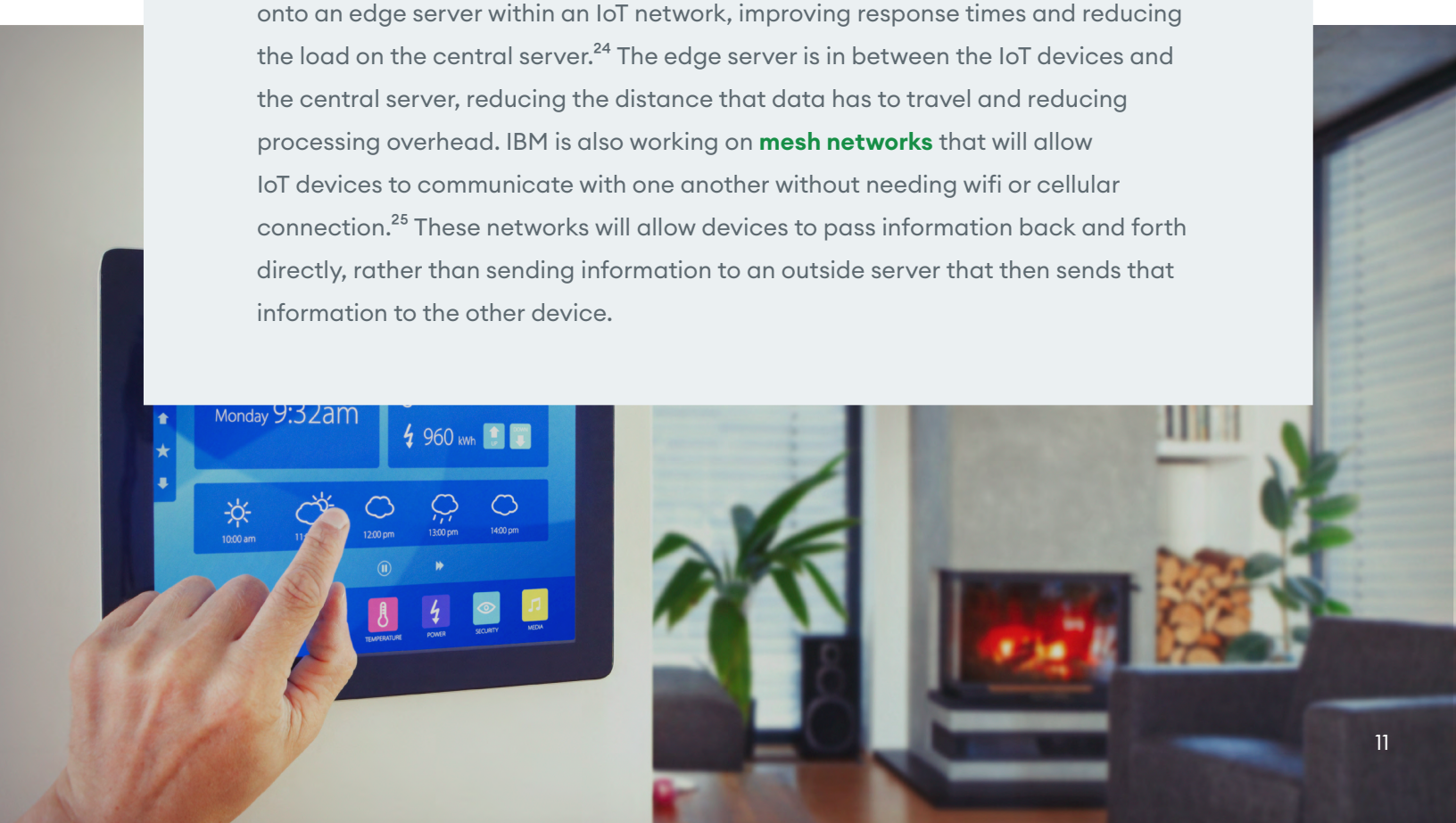
Microsoft's cloud computing platform is known as Microsoft Azure. Azure works much the same way, licensing software and resources to businesses and IoT projects to help them get off of the ground. In the way of edge computing, Microsoft offers **Azure IoT Edge**.[20] This feature moves cloud computing technology onto the devices in a particular IoT network, reducing the workload on an IoT system's cloud. (need statement/description here about MSFT Digital Twin) One of the major benefits Azure IoT Edge is the ability to **move AI tasks** from the cloud to IoT devices themselves.[21] This means that AI processes can be running in your IoT project without the need for cloud connectivity. Azure IoT Edge also improves the latency of an IoT project while still cutting overall costs.

Google

While implemented a little later than Microsoft and Amazon's edge computing solutions, Google's **Cloud IoT Edge** is a powerful platform for IoT projects looking to make their foray into edge computing.[22] Their edge computing solution is a physical **TPU** - Tensor Processing Unit - which is a small processing chip that can be custom-tailored to an IoT project's needs.[23] These chips are smaller than a penny and consume very little power, making them easy to integrate into a device's design. The main selling point of these TPUs is their ability to push AI to the edge. This is especially significant for Google, as AI is something that the company has been investing heavily in for close to a decade.

IBM

While IBM exists behind the scenes in most of today's technology, IoT and edge computing is one area where the company is leading in innovation. Their **Edge Analytics in the Watson IoT Platform** pushes certain process and applications onto an edge server within an IoT network, improving response times and reducing the load on the central server.[24] The edge server is in between the IoT devices and the central server, reducing the distance that data has to travel and reducing processing overhead. IBM is also working on **mesh networks** that will allow IoT devices to communicate with one another without needing wifi or cellular connection.[25] These networks will allow devices to pass information back and forth directly, rather than sending information to an outside server that then sends that information to the other device.



Cisco

Cisco has been working on device networking since its founding in the 1980s and is still in the game nearly 40 years later. Their **Kinetic IoT platform** is designed to help businesses across industries improve their efficiency, capabilities, and cloud security through IoT.[26] They recently unveiled **Edge Fog Fabric**, which is an open architecture IoT platform that gives IoT devices on Cisco's Kinetic platform the ability to perform computational tasks on the devices that create data.[27] This gives IoT systems the ability to be even more scalable and efficient, streamlining the entire IoT process. EFF is primarily targeted at businesses and specific industries rather than the IoT market as a whole.

Dell

Dell launched its IoT division back in 2017, intending to invest $1 billion into the industry by 2020. During this time they've created several systems for the IoT market, all revolving around **making the IoT process smarter**.[28] This includes implementing AI and deep learning throughout their IoT systems, which allows them to manage data more efficiently. Dell has also created a line of **Edge Computing Gateways**.[29] These are physical devices that you can install into your IoT system. They take in data from nearby devices and sensors, performing as many computational processes as they can before sending anything into the cloud. These devices make it easy to implement edge computing into an IoT project, as they blend into existing projects fairly seamlessly.

Foghorn

Foghorn is a relatively new tech company with a sole focus on edge computing solutions.[30] Despite being new in the game, they already have significant backing from industry leaders like Dell, Bosch, General Electric, and Intel. Their solutions are intended for the industrial sectors, including transportation, oil and gas, and renewable energy. The company not only pushes IoT computing to the edge, but also does so while incorporating things like machine learning, artificial intelligence, and real-time analytics. Their **Lightning platform** implements edge computing in a small footprint with large-scale capabilities. Foghorn's services are cloud agnostic, which means you can use them with whatever IoT platform you are currently using.[31]

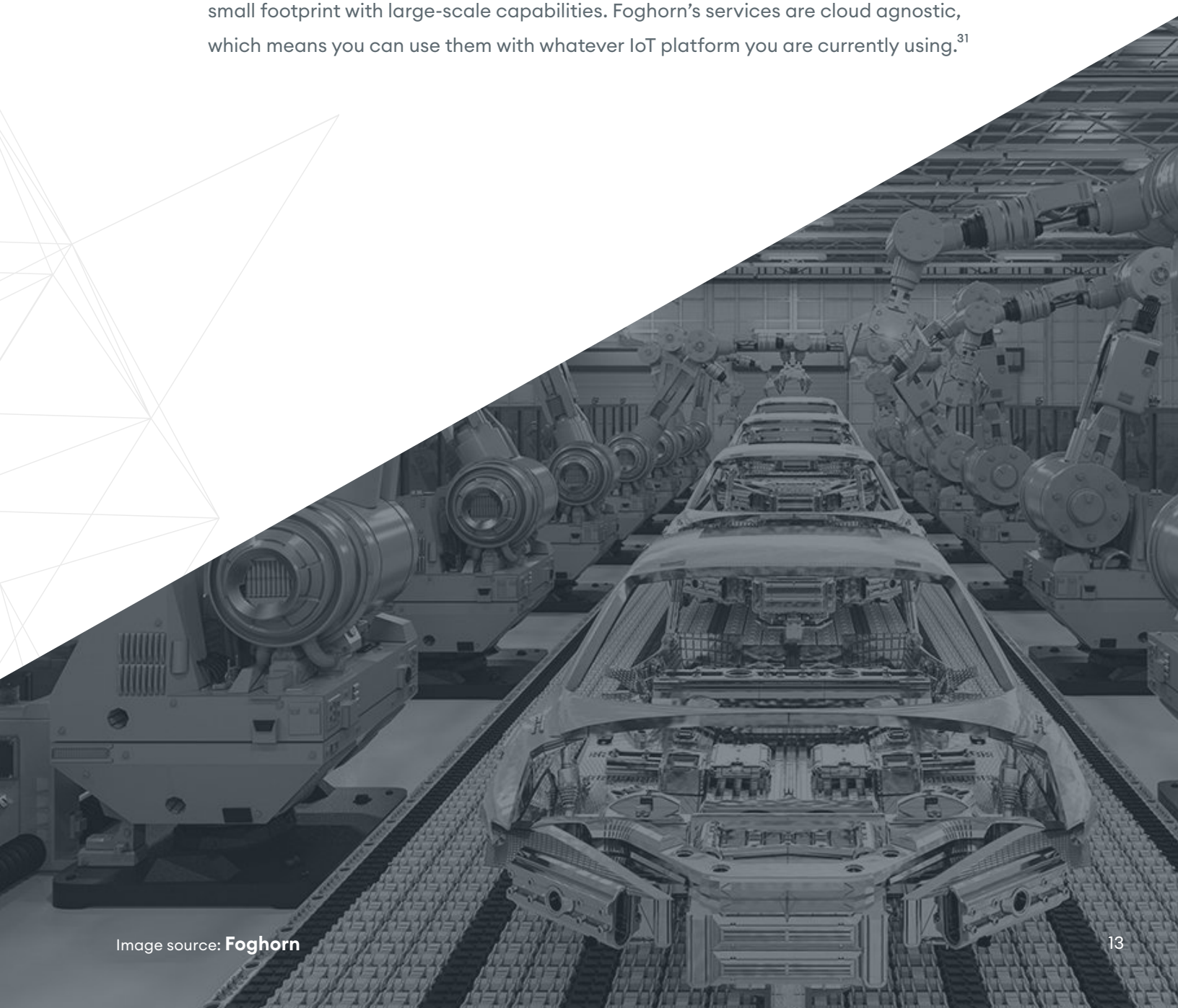


Image source: **Foghorn**

Industry Applications, Use Cases, and Examples

Many of today's emerging technologies have reached a bit of a standstill, at least in terms of getting things out of the lab and into the real world. Technologies like AI, AR/VR, IoT, and fully self-driving vehicles simply aren't able to provide the experiences that consumers and businesses want without a new way of computing.

When done correctly, edge computing technology can help solve this problem. It pushes everything onto the physical devices that make up these systems, reducing how much these technologies rely on outside forces. With edge computing, our devices would be able to do more without having to communicate with a cloud server or external service.

Here are some of the ways that edge computing is expected to impact our personal and professional lives.

IoT

- Hewlett-Packard made **a recent announcement** for its plan to invest $4 billion into its Intelligent Edge department, which offers edge computing solutions like data storage and computing where the data is being collected.[32]

- FairCom - a company that specializes in database technology - recently introduced the **c-treeEDGE IoT database solution**. It enables businesses to deploy their edge computing databases at the gateway level.[33]

- **Crown Castle and American Tower** - two of leaders in the cell tower industry - have shown an interest in edge computing technology and 5G use cases.[34]

- Portland-based startup Rigado managed to bring in **more than $15 million** during an investment round.[35] This money will go towards the IoT industry, specifically edge computing services that enable things like smart buildings, asset tracking, connected retail, and more.

Networking

- While working on a solution for trading cryptocurrency, Acute Angle ended up creating **a new form of cloud infrastructure**.[36] This new kind of cloud technology would provide all of the traditional features of a cloud, but instead of their being a central cloud server, the cloud would be made up of all of the connected devices.

- LinkedIn thinks that edge computing is the future of modern data centers, believing that it will enable processes to be **completed at cell towers** before data is ever sent back to internet-based companies.[37]

- Last year, Cisco unveiled its **Edge Computing Gateways**, which are small hardware devices that can be used to perform computing processes locally within an IoT network. [38]

- The **Cisco C-Series C4200 multinode rack server** is a new device for IoT that provides 128% more processor core density and 33% more memory compared to previous models, stretching the computing possibilities at the edge even further.[39]

Infrastructure/Machine Learning

- In 2018, SWIM.AI - an AI and edge computing firm - unveiled a set of **IoT and smart city solutions**.[40] These services use SWIM.AI's EDX software to push analytics, machine learning, and computing to the edge of IoT. These services are helping to make smart cities a reality by bringing IoT applications like water and energy management to the urban landscape.

- Renovo - a company that offers an open-source autonomous vehicle platform - has partnered with EdgeConneX - and edge computing provider - to push as many of the processes in self-driving vehicles **onto the vehicle itself**. [41] This helps reduce latency and bandwidth while opening the door for revenue to be made from vehicle data.

- NXP Semiconductors - a secure connectivity solutions provider - has partnered with several global systems providers to create a secure infrastructure for edge computing. This solution will bring machine learning and artificial intelligence to the edge of IoT.

Consumer Devices

- For autonomous vehicles to remain safe and effective, they have to be able to make near-instantaneous decisions and calculations. This can't be achieved by sending and receiving data through a cloud server while the vehicle is in motion. Finding routes, using AI, accident prevention - all of these processes have to happen on the vehicle itself for full autonomy to become a reality. Edge computing could bring new capabilities to self-driving vehicles and help move the industry forward.

- As AR/VR experiences become increasingly popular and advanced, the devices themselves will need to become more powerful to maintain user immersion. As it is today, very few AR/VR devices can be used without a connection to a host computer. Edge computing technology will help push all of the processes onto AR/VR headsets, making the devices more immersive and capable.

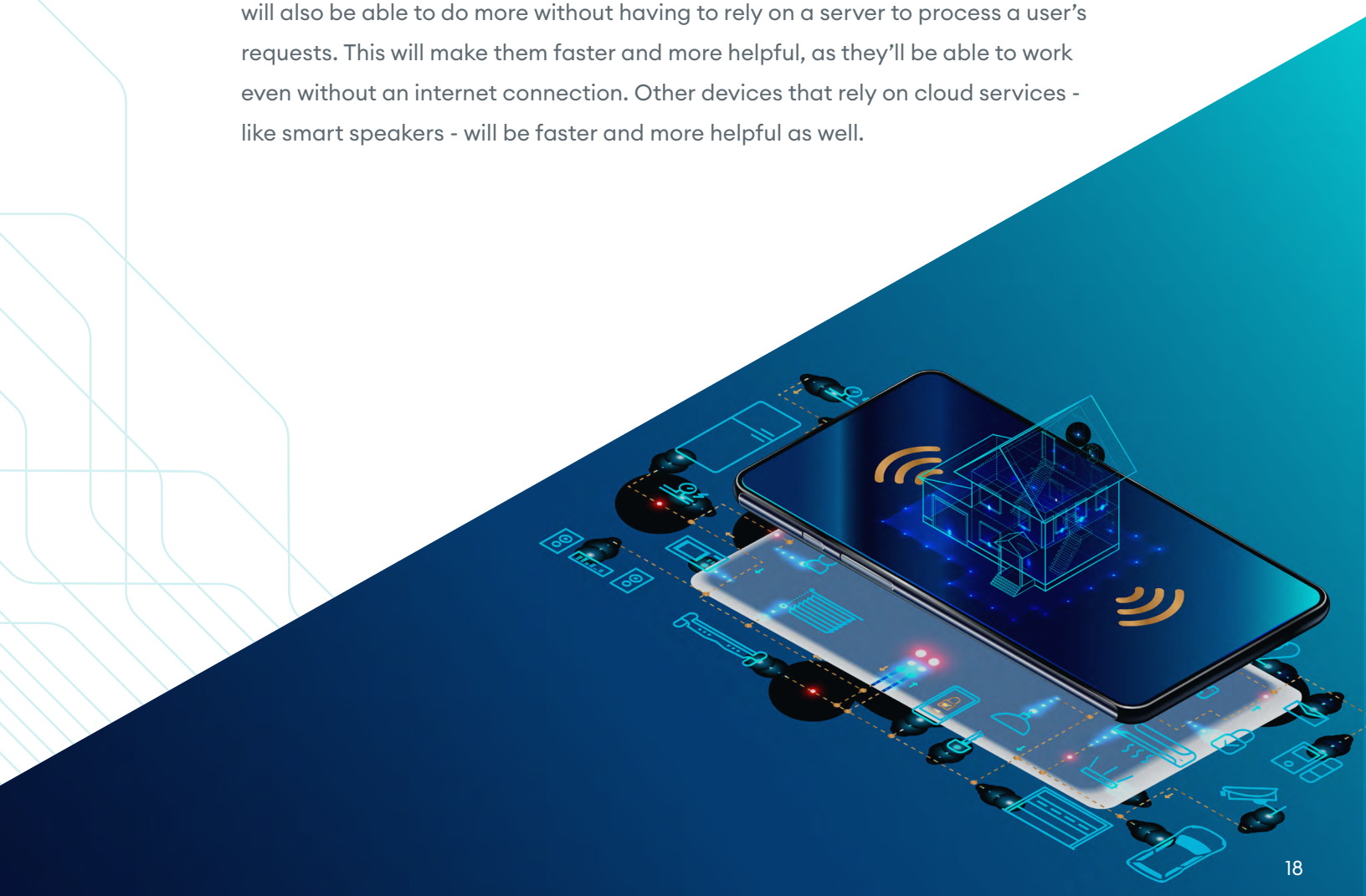
- Personal assistants like Siri, Alexa, and Google Assistant spend a lot of time communicating with cloud servers to accomplish requests. This is why you may find them less than helpful when you are outside of wifi or cellular services. With edge computing technology, these assistants would be able to perform most or all of a user's requests without the need to connect to the internet.

The Future State of the Industry

Key Predictions

Edge computing is expected to impact IoT more than any other industry by a wide margin. It will make IoT technology more realistic, scalable, and powerful in the long term by reducing the load on external servers and improving the capabilities of IoT devices. Networks will also become substantially faster due to improvements in edge computing. With devices doing the majority of the computing work - rather than sending requests off to remote servers - networks will be freer and less encumbered by streams of data from devices. Networks will only be used when they have something to offer that devices don't.

Smart assistants like Siri, Amazon Alexa, Samsung Bixby, and Google Assistant will also be able to do more without having to rely on a server to process a user's requests. This will make them faster and more helpful, as they'll be able to work even without an internet connection. Other devices that rely on cloud services - like smart speakers - will be faster and more helpful as well.



How It Will Affect Consumers

The most obvious benefit that consumers will experience thanks to edge computing is faster, more capable devices. Cloud services and remote servers enabled an entire age of technology that otherwise wouldn't have been possible. However, that dependence on outside services has led to a cap on what our devices are capable of. Not to mention that every process that needs to be made by an external server is slowing down networks with extra data. Edge computing will relieve the strain on networks while also making our devices more independent and powerful.

A less obvious - but arguably more important - benefit of edge computing is a massive increase in consumer privacy. The more of your data that has to be sent to an external server/cloud, the less control you have over your digital presence. Not to mention that servers and networks are much more susceptible to being hacked than personal devices, as the rewards for a successful hacking attempt are much greater. By keeping more of the user's personal data on their device, there is more consumer privacy and less risk for data to be abused.

How It Will Affect Businesses

As much as consumers are expected to benefit from edge computing, by far the biggest beneficiaries of edge computing are going to be businesses. Across every industry, companies will become more flexible, adaptable, and agile. Edge computing will open the door for faster processing, allowing companies to make smarter, faster decisions.

Machinery will also be able to operate faster since the machines will be able to process many things independently. This means that companies can provide faster services to their customers.

Businesses will be able to offer consumers greater privacy, as well, when it comes to their data and devices. This has become a hot topic in recent years, so companies that can use edge computing as a way to sell the security of their products will have an advantage over their competitors. The data generated by IoT and edge computing will also provide businesses with new insights into their customers, allowing products to be more personalized and streamlined than ever.

Optimize Your Workflow with Edge Computing

While edge computing has been around for over a decade - and arguably was the only kind of computing before the cloud - it is only in the last few years that its importance to the world is being realized. Several emerging tech industries, such as IoT, AI, AR/VR, are in desperate need of the flexibility and processing power that edge computing has to offer. It can streamline existing tech, make it more secure, and cut the costs that these more advanced technologies inevitably incur.

The examples listed in this paper are just the first glimpse into the future that edge computing has in store for us. Being proactive about implementing this new technology into your workflow will keep your business agile and innovative while also opening up new ways to serve your customers.

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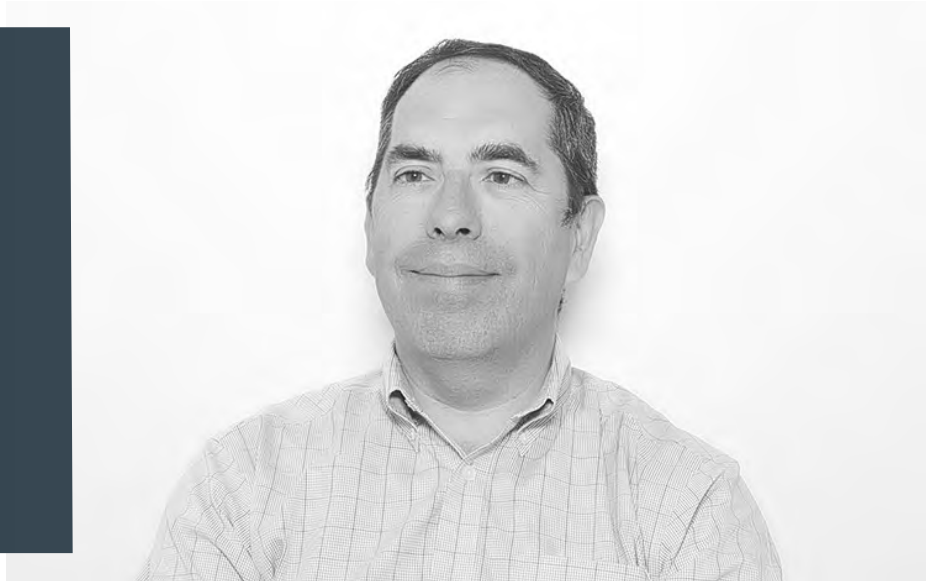

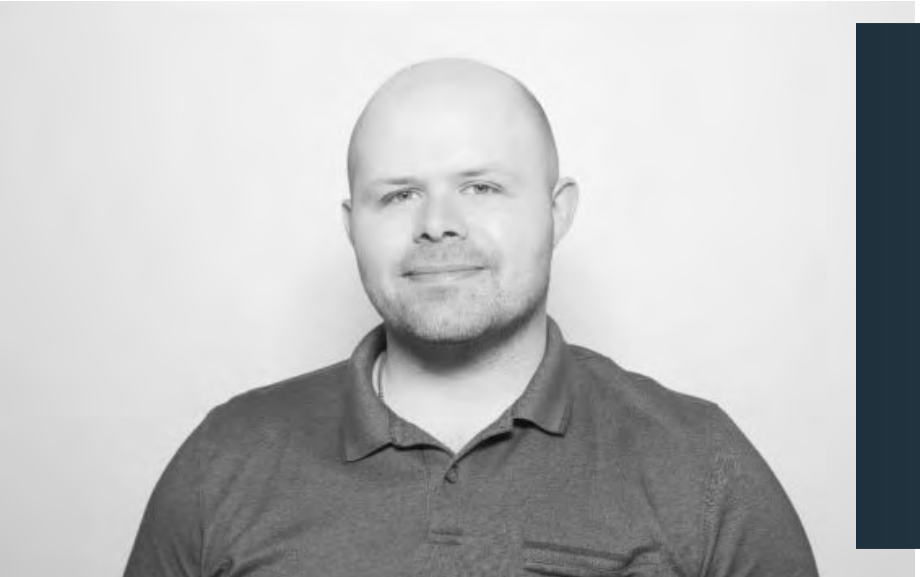

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