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CHAPTER 8

EDGE COMPUTING AND IOT STARTUP APPLICATIONS

DR.LAV SRIVASTAVA
ASSISTANT PROFESSOR, DEPARTMENT OF COMMERCE,
LUCKNOW PUBLIC COLLEGE OF PROFESSIONAL STUDIES,
UNIVERSITY OF LUCKNOW, LUCKNOW, UTTAR PRADESH, INDIA.

RESHABH DEV
ASSISTANT PROFESSOR, DEPARTMENT OF MANAGEMENT,
LUCKNOW PUBLIC COLLEGE OF PROFESSIONAL STUDIES,
UNIVERSITY OF LUCKNOW, LUCKNOW, UTTAR PRADESH, INDIA
Corresponding Author: reshabhdev1993@gmail.com

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ABSTRACT

This chapter uses real-world applications to demonstrate how edge computing transforms IoT applications in IIoT, smart homes, and healthcare. Through these case studies, one can clearly see how edge computing can be beneficial in supporting business people in delivering scalable, secure and efficient solutions. The problem is that those IoT firms that are applying edge computing today are positioning themselves for success in a rapidly evolving technological landscape in addition to addressing current issues. The continuous application of edge computing is set to be standardized, and this is as the IoT industry advances. Those businesses leveraging this promise will be better placed to promulgate innovation, engage with many of the issues that define modern IoT deployments, and, ultimately, thrive. This is why, writing this chapter, I want to encourage entrepreneurs to utilize this revolutionizing technology to its potential by clearly

understanding how edge computing works for IoT startups.

8.1 INTRODUCTION

The Internet of Things (IoT) emerged as an innovative technology enabler that essentially links various devices, sensors and systems to collect, process and respond to data. This new networked environment created a new and sustainable environment of innovations that included building up methods and decisions and improving the quality of life. However, with increasing levels of IoT application usage, issues such as high latency, limited bandwidth, and data integrity and security concerns reduce their efficiency. The general approach to addressing these challenges requires turning the traditional approach of managing data upside down – that is where trend edge computing comes with the solution. Edge computing is an information processing paradigm where data and computing are conducted at the edge or near the data source rather than relegated to the cloud.

The specifics of the IoT business environment are primarily rapid activity, often carried out in conditions of relatively scarce resources. These firms can now solve real-time computation needs in autonomous vehicles, health care, and industrial IoT fields. Therefore, with the given data processing proximity, startups can serve their purposes more effectively by entering the consistently growing and competitive market with more reliability, better user experience, and fewer operating expenses. This chapter first highlights the concept of edge computing and explains that it is crucial for IoT startups. It looks at the gains achieved with the adoption of the technology, which includes lower latency, greater bandwidth, and better security and reliability. It then presents tactical considerations for incorporating edge computing into IoT systems, including decentralized system structure, edge AI, and hybrid cloud edge. The chapter also covers problems encountered while creating a new enterprise, including the following topics: Expense of infrastructure, Control of distributed systems, and assurance of a high level of security in all nodes.

8.2 BENEFITS OF EDGE COMPUTING FOR INTERNET OF THINGS STARTUPS

- **Decreased Latency:** For events analysis and reaction, edge computing reduces the response time to nearly insignificant due to data being analyzed at or just a little away from where the data was generated. In business automation over the

Internet of Things, industrial applications, smart traffic systems, and driverless cars that call for quick reactions, this element of latency is critical. For example, edge devices can quickly diagnose equipment issues in industrial use, minimizing costly downtime and enhancing efficiency. Time-sensitive applications can still have a competitive advantage for startups; Communication latencies in sending data to centralized cloud servers could be reduced, equalling better user experiences.

- **Enhanced Bandwidth Efficiency:** The utilization of centralized cloud servers may exert much pressure on bandwidth, given the massive amount of data generated by IoT devices. This burden is reduced by edge computing since it filters, processes, and analyses data locally. Personal data that may be useful only in the long term or for specific analytics is transferred to the cloud. For example, in the smart surveillance system based on edge computing technologies, video streams may be thoroughly analyzed, and only alarms or brief reports can be transferred to the cloud. This also makes it easier to respond and make decisions quickly, apart from reducing bandwidth usage and cost.

- **Implementation of smart technologies in healthcare generally contributed to better Data Security and Privacy:** New IoT companies in industries such as healthcare, banking, and smart city systems usually involve sensitive data, so data security and privacy are key concerns. Startups might limit data exposure in transit and decrease the threats of breaches and unauthorized access by analyzing data locally at the perimeter. Also, the firms may stay compliant with strict data protection regulations like the GDPR and HIPAA if the outlined approach is localized. For example, wearable health devices may perform analyses on patient data locally and transmit only the minimum necessary information or aggregate information to the cloud to ensure patient privacy compliance and enable actionable insights.

- **Increased Reliability:** Edge computing increases the reliability of IoT applications by ensuring the continued functioning of the processes caused by the interruption or lack of access to large centralized cloud databases. This is especially helpful for remote or key IoT deployments, such as off-shore oil drilling platforms, farm systems, and disaster occurrence systems. Edge devices may further run and give real-time data, which is timely since they work offline analyzing data. For instance, an edge computing-based precision agricultural

system can provide the best irrigation and fertilization schedule during internet outages in a few cases, thereby stemming long-term production and resources.

8.3 STRATEGIES FOR THE IMPLEMENTATION OF IOT STARTUPS

- **Architecture design can be decentralized:** Dispersed IoT solutions architecture planning is a strategic way to undertake edge computing for firms interested in optimizing it. In this paradigm, data is first analyzed near the source, so there is less reliance on the central cloud control. This method is useful for applications needing immediate data acquisition, processing, and localized decisions, including drones, Smart Grids, and Wearable Medical Equipment. Decisions on which devices to support should be made so that the target edge devices have enough computing capabilities and the interactions with current devices are seamless. It explained that some startups may attain a low latency, cheaper operating costs, and superior system architectures where data processing is decentralized.

- **Leveraging Edge AI:** Edge computing and AI are a strong approach to real-time decision-making from the network's edge. Through machine learning, local computing lets devices learn and respond progressively to complex scenarios on the edge rather than necessarily having to go online. This capacity is very useful in predictive maintenance. Edge AI can analyze sensor data for machinery and predict failures before they happen. Smart city control can also enable traffic control in real-time within the city through the information transmitted by networked traffic lights and sensors. Consumer products may be personalized by startups intending to use artificial intelligence models trained on people’s individualistic behaviour, such as fitness tracking devices or smart personal assistants.

- **Hybrid Cloud-Edge Integration:** Edge and cloud integration allow scalability and efficiency so that companies can maximize their resources. Sensitization data may be processed locally at the edge, whereas non-latency-critical data is stored and processed in the cloud for more extended stats. This method serves the best interest of IoT firms with different data processing needs. For example, in a logistics business, edge devices may capture the current conditions of fleets and send them to the cloud for historical analysis for route optimization and demand forecast. By embracing a hybrid architecture, companies may get the two most desirable attributes of real-time and vast analysis.

8.4 CHALLENGES IN EDGE COMPUTING ADOPTION

8.4.1 INFRASTRUCTURE COSTS

This makes edge computing expensive regarding infrastructure, hardware resources, software solutions, and skilled human labour. One of the major challenges is that the deployment of edge servers, devices, and connectivity solutions involves capital expenditures, anything from investments in new GM patents to base stations and the actual servers, which may prove a herculean task for the companies, especially if they are operating under tight or lean budgets. Such financial barriers can be highly challenging to the various startups and small businesses that these firms target. Nevertheless, most of these costs are manageable with the help of established patterns in cooperation with hardware manufacturers and cloud solutions providers. Joint ventures may allow the firms to spread out costs when accessing technologies that they couldn't afford on their own. Industrial building concepts, such as modularity and scalability, make the best approach to control infrastructure overheads. These systems enable the organization to acquire edge computing capabilities modularly and match upgrades to business development and demand. Thus, Edge computing enables enterprises to integrate the system in phases and save money from the large capital investment required. Also, engaging pay-as-you-go solutions provided by cloud service providers also minimizes financial pressures; thereby, these firms can leverage state-of-the-art technological infrastructures without considerable investments at their initiation. This slow process enables the firms to overcome the financial reality while realizing the huge potential of edge computing.

8.4.2 MANAGING DISTRIBUTED SYSTEMS

Regarding network configuration, edge computing complicates these particulars by having multiple nodes in several places. Thus, the systems for handling this data type must synchronize within an edge environment since the nodes in question have to facilitate fast communication. Synchronization issues crop up as these nodes have to communicate with the central system and other nodes, in many cases, in real time. The disadvantages of mismanagement of these systems include increased operation rates, delays in services and non-uniformity of data.

Getting over these issues calls for applying proper orchestration features and standards. These include applications that enhance the operation of edge networks in

terms of communication, monitoring, performance, and resource management. However, for each of these solutions, there are expenses which can become easily unmanageable for young companies. In response to these difficulties, firms may consider automation technologies and central monitoring platforms to address the issues of distributed networks. They augment the organization's functionality by minimizing the likelihood of intervention in edge-node performances.

Further, applying leading-edge technologies, particularly artificial intelligence technologies, including AI and ML, for predictive maintenance and decision automation can enhance distributed system management. Through our findings, we identify insights related to identifying suitable management solutions, which firms can utilize to address the operational issues affected by distributed edge networks – whilst maximizing performance and stability.

8.4.3 SECURITY CONCERNS

Security concerns come as a consequence of decentralized nodes characteristic of edge computing. Every edge device – each of the units that form the information gathering and processing centres – becomes vulnerable to cyber threats. Criminals may invade edge devices to steal information or interrupt functionality and use these devices to launch a more extensive cyberattack on networks. Therefore, companies engaged in implementing edge computing need to ensure safety standards to prevent attacks on the systems.

Protection of edge devices is not only a technical issue. Secure data must be implemented at transit and storage to enhance its security so that unauthorized persons cannot read it. Two-factor authentication (2FA), also commonly referred to as two-step verification, is an umbrella term regarding schemes that include multi-factor authentication (MFA) that protect by requiring users to give two or more factors of identification rather than a single password. Continuous conforming firmware upgrades are mandatory to address security holes and to ward off threats. Applying the zero-trust security structure provides a complex approach to protect edge computing contexts. This concept works on constant validation, which validates every device, user, and network connection. This way, following the zero-trust model, reducing risks connected with compromised devices or unauthorized access is possible.

Even though strong security measures provide effective protection, they also have implications in terms of cost and organizational flexibility. Corporations can look at automated security surveillance devices, threat identification devices, and employee training in response to these threats. Regarding security issues, foresight allows companies to harness the full benefits of edge computing with little limitations to risks and threats.

8.4.4 LATENCY AND BANDWIDTH CONSTRAINTS

Collecting and processing information consumes time. Thus, edge computing aims to provide fast access to data through its proximity to sources, hence the need for consistent low latency across various environments. Thus, while edge computing helps repudiate the dependence on large and often distant data centres with high latency in information transfer, new challenges related to high latency at the edge may occur if the connections are unstable, the edge infrastructure is insufficient, or the data processing pipelines are congested. In reaction time-critical applications, the response time necessary for synchronization has to be minimal. Since autonomous vehicles or remote, monitored human bodies are life-safety-critical applications, the impact on human life from even a tiny reaction time can be disastrous.

Limits in bandwidth exacerbate this. Even though edge computing prevents data from being sent to a main server, some apps still must complete extensive data synchronization. Real-life videos, updates for the Internet of Things devices, and handling intricate data analysis require a lot of bandwidth, which can put much pressure on the current networks. However, the scarcity of high internet speeds in remote or developing regions magnifies these challenges and slows down edge solutions deployment. These challenges mean that there needs to be an investment in improved networking infrastructure, i.e. G technology, which provides greater bandwidth with less delay. Further, these edge systems require data filtering and compression to minimize the amount of transmitted data while prioritizing critical data. Although these strategies work profoundly, their execution can be complex and resource-intense – thus presenting a challenge to companies of a smaller scale.

8.4.5 INTEROPERABILITY ISSUES

Edge computing solutions consist of several hardware platforms, software platforms and connectivity solutions provided by multi-vendors. One of the main difficulties in managing such a structure is how the various components interface. Maturity issue

III: There is no standard for protocols in most edge devices and platforms; therefore, incompatible issues arise. For instance, an Io T sensor from one vendor may not integrate well with another analyst tool, resulting in several isolated data networks and costly business processes. Such compatibility challenges may slow down the rate of new development and design difficulties when increasing the size of a given system. It is still up to businesses to spend extra dollars to create specific connectivity scenarios or middleware agencies, amounting to higher costs and difficult implementations. To startups and small enterprises, these hurdles can push back project schedules and expensive-scared capital from sale activities.

To this end, the industry can prevent and control only by increasing the relevance of standardization frameworks and protocols. Free software products and standards developed under the consortium can also be compatible to prevent situations where vendors have full control. However, for these standards to become fully adopted across players in the industry, coordination is often needed, and it could take time. Organizations have to unlearn what it means to use edge computing and allow for some fluidity and compatibility issues in the pursuit of using modular systems to create more applications.

8.4.6 SCALABILITY CHALLENGES

While scalability is one of the pillars of edge computing, actual implementation can be a stiff challenge. By contrast, scaling is an expanded operation, frequently across multiple locations and often distributed geographically in edge environments. This can be done by integrating more edge devices, guaranteeing network connections, and keeping up with the performance statistics of all facilities. Issues of scale are most severe concerning ‘‘volumes’’ in industries experiencing variations in demand. For instance, a retail firm may need extra edge resources to handle more customers during some period. Still, acquiring this extra capacity means extra capital when demand is low and resources are underutilized. Similarly, in manufacturing, the dynamic scaling of demand also rises with season- or project-based production. Firms require sophisticated operational resource management solutions and sound infrastructural architectures to overcome these challenges. Edge systems need to be adaptable, where they can provide resources according to the requirements that machines and devices will have in the future by implementing AI solutions for prediction. However, integrating such solutions poses some limitations, and they are usually expensive because they require highly trained staff and usually novel technologies.

8.4.7 LIMITED EDGE EXPERTISE

The growth of edge computing has imposed a challenge because while the technology is developing quickly, the supply of professionals suitable for deploying, designing, and managing the systems is limited. They called edge computing an 'interdisciplinary domain', as it involves elements of design and development at both the hardware and software level, network architecture, and security issues. To manage hiring with this type of dual competency is difficult, especially if operating in areas where the advanced use of technology is slowly surfacing.

The lack of professionals also goes beyond difficulties in searching and selecting staff. In this environment, even though skilled employees can be secured, continually training these people to counter technological change becomes essential. Employees need training and professional development, which is an additional cost to the company, and all expenses must be covered in one way or another. To startups, this can shift focus and funds away from essential operations, thus adding more barriers to implementing edge computing. These people can be hired to work with your company, or a managed service provider can be hired to work with your company, depending on your company's risk tolerance and willingness to outsource the management of its systems to an external entity. To avoid such a problem, businesses need to establish strategic partnerships with academic institutions, provide internships, and attend forums to access talents and /or new knowledge.

8.4.8 ENERGY EFFICIENCY AND SUSTAINABILITY CONCERNS

The Employment of numerous edge devices in different places results in the overall energy use of an organization. Regarding power consumption in edge computing systems, the original motivation of decreasing the demand for data centre energy consumption can be easily overshadowed by the requirements of distributed devices. This challenge is most relevant for companies trying to achieve sustainability objectives or follow the legal requirements concerning the environment. This means that energy management in edge devices is already a struggle, let alone when these devices are deployed in remote or low-resource settings, as they might be using unreliable energy sources. Moreover, as organizations expand the number of edge computing networks, there is a huge environmental consciousness in manufacturing and deploying edge infrastructure.

Appropriate hardware should be used to solve these issues, and the possibilities of utilizing renewable power for edge devices should be considered. Smart power control strategies can help to achieve improved device utilization without higher power consumption. However, these solutions involve high initial costs aimed at research and development and make sustainability a costly concept for companies implementing edge computing.

8.5 REAL-WORLD USE CASES

8.5.1 SMART HOMES

Edge computing continues reshaping the smart home environment by supporting premature and localized computations for Intelligent Things (IoT). Smart gadgets like smart thermostats, smart lighting, smart cams, security and smart voice assistants incorporate edge computing to process data locally and not rely much on cloud servers. It will also help produce fewer delays, better privacy, and improved consumer use due to the localized processing. For instance, a smart doorbell embedded with edge AI can detect faces right from video streams. This sort of system can easily distinguish between strangers and members of the household and contacts homeowners only when required, thus reducing false alarms.

Furthermore, DC, as a part of the EC, supports energy management in smart homes by controlling the attached devices, which rely on the analysis of real-time data. For example, intelligent temperature control enabled through an edge interface can learn about the user and adjust the heater or cooler to fit the preferences without wasting too much energy. Not just convenience but also sustainable agendas benefit from this capability. In addition, because smart home devices process data locally, the technologies do not require the sustained use of a network, which will allow for persistent service even in cases of network disruption. The integration of improved privacy and speed with dependable connection renders the sovereignty of edge computing in smart home systems exceptional.

8.5.2 HEALTHCARE

In healthcare, edge computing is now seeping into various spheres to increase the value delivered to patients. This means that through processing data on the edge, devices such as wedding garments and medical equipment can watch and respond to the patient's state periodically. For example, an edge-integrated cardiac monitor can independently detect arrhythmias from the patient's heart data. This early detection

coddles healthcare professionals to take early action against it and, therefore, prevents the patient from developing severe complications, let alone death.

Edge computing also solves the issue of data privacy in healthcare. The application of the technology processes the information locally either on the devices or, preferably, hospital networks, therefore minimizing data exposure to headquarters servers. RPM solutions stand to gain greatly from edge computing in a way that ensures that patient vital information is analyzed and addressed in real time. For instance, diabetic patients can wear small monitoring devices notifying them and caregivers of abnormal levels of sugar in the blood; patients with certain diseases can be fitted with implantable devices to control their disease.

In addition, edge computing enhances highly specialized medical use cases, including surgery, through surgical robots and telemedicine. These systems need low latency and high-reliability networking provided by edge computing. Indeed, the prospect of improving diagnosis, treatment, and overall patient care becomes ever more realistic as more and more of the healthcare field embraces edge technologies.

8.5.3 INDUSTRIAL IOT (IIOT)

Another area where edge computing is making radical improvements is the Industrial Internet of Things (IIoT). Manufacturing plants, oil refineries, and supply chain solution centres rely on edge technologies to improve processes, increase safety, and decrease waste. Process data on IIoT devices at the edge so they can work in real-time, detect deviations and anticipate maintenance requirements without failure. This approach of maintenance controls avoidable downtimes and, therefore, cuts repair expenses and prolongs equipment use in industries.

More specifically, edge-enabled robots are highly disruptive in manufacturing verticals. These robots localize data processing to adjust to changeable assembly line conditions and execute operations more accurately. For example, an edge-controlled robotic arm in an automotive manufacturing system may adapt the movement plan on the fly based on variations in part size or geometry so that the quality of part production will not be affected.

Edge computing can improve security in the oil and gas business by actively tracking important aspects such as temperature, pressure, and vibration. Any slight changes in these normal operation conditions cause an alarm to be raised, thus reducing or eliminating any possible mishaps. As with other industries, logistics firms use edge

computing to monitor assets, in this case shipments, to ensure that they get to their destination promptly and with minimal disruptions to the supply chain. Overall, edge computing can change the industrial perspective by decentralizing data processing and enabling real-time decision-making, enhancing process efficiency, reliability, and adaptability to demands.

8.6 THE CALL TO ACTION FOR IOT ENTREPRENEURS

Edge computing is not only about solving relevant issues in today's world. It is about defining what IoT will be tomorrow. So, anyone who operates in the IoT industry and is excited about the future of this technology should welcome this change. Edge computing gives newcomers a unique position in the market, provides value-based solutions that will help seize the relevant niches in the digital economy, and improve competitive advantages in a highly competitive environment. In addition, entrepreneurs must focus on other capabilities within edge computing, including decentralized compensation, edge AI, and hybrid cloud architecture. This enables them to develop amazing and unique products and services that suit the ever-changing customer and business markets.

8.7 CONCLUSION

Applications of IoT have been on the rise in IoT because of edge computing, and organizations can develop interesting, effective and secure strategies at aTZM. One can construct the value proposition for a more connected world using features spearheading edge computing, including latency bandwidth and security. It also enables institutions to deliver immediate responses and apply assets appropriately. It has solid data protection necessary for the expanding vivid IoT sphere.

IoT firms will need edge computing integration to remain relevant as a crucial element in the current and future IoT market. They can use decentralized architectural designs and employ edge AI, integrate balanced outcomes of cloud-edge models, and get to new levels of creativity and scaling. Moreover, in the coming years, edge computing will not only solve existing problems but also open the doors to future IoT innovation opportunities because the cost and challenges related to edge computing are expected to reduce with technological advancement. Such startups that adopt this technology in the present or current day will be poised to benefit the most in the future connected world and develop products and services that will revolutionize efficiency, security, and user interface in the digital economy.

8.8 CASE STUDY: FLEET MANAGEMENT WITH EDGE COMPUTING

The concept of edge computing is fast transforming industries because it enables on-the-sky processing of data. The logistics industry's capabilities are being harnessed to revolutionize fleet management. The revolutionary capability of edge computing is exemplified by the innovative firm FleetEdge, which incorporates the concept into the firm to resolve challenges such as real-time monitoring, production, and sustainability.

8.8.1 EVALUATION OF METAL OXIDE SEMICONDUCTOR IN REAL-TIME MONITORING AND DECISION MAKING

Cars featured by FleetEdge are fitted with edge devices that help perform calculations without going online. They are designed to emulate and study, in real-time, geolocation information, engine state, fuel economy, or driver behaviour. FleetEdge minimizes latency by analyzing this information at the edge to provide a fast response to vital events. For example, if a vehicle has some issues with the engine, the edge device informs the driver and the fleet management, enabling them to fix it before it causes a failure. This dramatically reduces time off the tool and inhibits costly stoppages. In addition, edge computing enables smooth operations such as GPS observing and the optimization of routes. Synchronous updates help to avoid traffic jams, choose the best path and follow delivery schedules. Boosting this form of monitoring is advantageous in improving the satisfaction level of clients as they receive accurate delivery dates and frequent progress reports.

8.8.2 CORPORATE EFFICIENCY THROUGH SMART INTELLIGENCE

FleetEdge can leverage everything edge computing offers to optimize its fleet function. Data processed at the local level is collected together and transmitted to other centralized systems for further evaluations at some time, if necessary. It reduces the burden of cloud infrastructure and provides the right insight into the best approach. For instance, it may identify patterns in fuel consumption and then propose how consumption may be improved. A case includes forceful braking or sudden acceleration, which FleetEdge utilizes to provide targeted training to enhance safe driving practices and maintain fewer trips on the vehicle. The real-time diagnostic can help to prioritize and schedule vehicles for servicing to help prolong assets, hence reducing the total operating cost.

8.8.3 SUSTAINABILITY AND ENVIRONMENTAL IMPACT

Sustainability is important to FleetEdge, and edge computing is necessary for a company to be environmentally conscious. FleetEdge saves fuel, practising more efficient route generation and avoiding unnecessary hours running the engine, decreasing greenhouse gas emissions. In addition, the technology encourages proactive driving behaviours that are friendly to the environment and have reduced the fleet's carbon footprint significantly. EVs form part of a revolutionary strategy in the current business world, and FleetEdge has integrated them into its strategic plan. Charging and discharge trends are observed by the edge devices so that energy can be used efficiently and extreme charging can be prevented, which results in battery deterioration. This feature allows for the transition to a green fleet featured in FleetEdge.

8.8.4 SCALABILITY AND FUTURE INNOVATIONS

The modularity of the developed edge computing solution allows FleetEdge to expand. If a new car or edge device is added, the firm does not have to redesign its architecture as it grows. This versatility especially ensures sustainability and cost advantage in the long run. This also applies, though, as FleetEdge is also eye-expanding on other modern technologies like artificial intelligence (AI) and the 5G connection. Susceptible edge-deployed AI algorithms may enhance the ability to conduct predictive maintenance and oversee fleets independently. On the other hand, 5G gives a low latency connection, which improves the system's reactivity and reliability.

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