Task Execution using Mobile Edge Computing

Bachelor In Computer Science

And

Engineering

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Introduction to Project

The project focuses on Mobile Edge Computing concepts, also known as Multi-access Edge Computing (MEC), which is a type of edge computing that brings the capabilities of cloud computing to the edge of the network. Originally centered around deploying edge nodes on the mobile network, this initiative, born out of the European Telecommunications Standards Institute (ETSI), has now expanded to include the fixed network or eventually converged network. MEC extends the functionalities of cloud computing, enabling powerful computing and storage resources closer to the users, resulting in enhanced network performance and lower latency.

Whereas traditional cloud computing occurs on remote servers that are situated far from the user and device, MEC allows processes to take place in base stations, central offices, and other aggregation points on the network.

By shifting the load of cloud computing to individual local servers, MEC helps reduce congestion on mobile networks and decrease latency, enhancing the quality of experience for end users.

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Scope of the Project

Mobile Edge Computing features can integrate with several domains such as the internet of things, artificial intelligence (AI), federated learning (FL) and fog computing to make the system more robust, elastic, efficient, and accurate.

When 5G will be launched it will increase speeds by up to ten times that of 4G, whereas mobile edge computing reduces latency by bringing compute capabilities into the network, closer to the end user.

Mobile edge computing use cases include:

- **Enterprise Mixed Reality (MR), Augmented Reality (AR) and Virtual Reality (VR) applications:**
  Mobile Edge Computing in AR/VR can support remote workers conduct maintenance and repair tasks in the field. A MEC solution would provide an overlay of rich information related to a particular asset they are repairing on the field force worker's display on a headset or mobile devices.

- **Cloud gaming and multiplayer gaming:**
  MEC would move the intensive compute/graphics processing from a dedicated gaming console, or a data center as cloud gaming grows, to the edge of the network. Gamers would have access to the same quality of game from a thinner client, anywhere within the network's coverage.

- **Real-time drone detection:**
  There is increasing need for solutions that detect when a drone has entered a secure, geo-fenced zone and to trigger necessary actions as defined by the security teams that manage the site.MEC keeps data from the drone closer to its source, reducing the time taken to react when there is a breach or a security threat.

- **Video analytics:**
  There is an increasing use of video surveillance in cities/enterprises, with data volumes growing, due to both the number of cameras and the quality of footage increasing. MEC enables local break out of traffic and analysis at the network edge, as opposed to routing the video traffic to central control for analysis. MEC reduces the cost, volume and time it takes to transport raw footage to the cloud/central server and allows for real-time triggers based on the analysis.

Technologies Used

- **JAVA:**

Java is a general-purpose, class-based, object-oriented computer programming language created by James Gosling at Sun Microsystems in 1995. It is intended to let application developers “write once, run anywhere” (WORA) meaning that compiled Java code can run on all platforms that support Java without the need for recompilation.

Java is one of the most popular programming languages and is used for developing a variety of applications, from business applications to mobile apps. It is a secure, reliable, and robust language that can help developers write code that is easier to maintain and reuse. It is also an interpreted language, meaning that the code is compiled on the fly as it is executed.

Java is a platform-independent language, meaning that the same code written in Java can be used on any platform that supports Java, such as Windows, Mac, Linux, and many others. This makes it ideal for developing applications that need to be compatible with multiple platforms. It also enables developers to write code in a modular fashion, which helps in the development of large applications.

Java is an object-oriented language, meaning that code is organized into objects and classes. This allows developers to create code that is easier to maintain and reuse.

- **EDGE CLOUDSIM:**

Edge CloudSim is a simulation tool that enables the deployment and management of distributed cloud computing systems. It was developed by the University of California, Irvine and is designed to help researchers and engineers understand the implications of cloud computing and its impact on distributed systems. Edge Cloud Sim allows users to simulate the interaction of distributed nodes, services, and applications in a cloud environment. It also enables users to develop and deploy cloud applications and services.

The Edge CloudSim simulator has three main modules: Cloud Infrastructure, Cloud Application, and Cloud Service. The Cloud Infrastructure module is responsible for creating and managing the virtual environment for the cloud simulation. It includes the creation of virtual machines, networks, and storage. The Cloud Application module is responsible for creating and deploying applications on the virtual cloud environment. It includes the development of application code, configuration management, and deployment. Finally, the Cloud Service module is responsible for managing the services provided by the cloud platform. It includes the provisioning of services, monitoring of usage, and the optimization of services.

- **XML:**

XML (Extensible Markup Language) is a markup language that is used to store and transport data. It is a language that is made up of elements, tags and attributes which are used to store data. XML is a text-based language that is used to store and transport structured data.

XML is a very important language in the current world. It is used in many different areas such as web development, data interchange, data storage, software development and much more. XML is used to store and transport data between different computers, applications, databases and web services. XML provides a way to structure and store data in a standardized way.

One of the most important benefits of XML is that it is easily readable by both humans and machines. XML is also a very flexible language, which makes it easy to modify and add new elements as needed. It is also platform independent, which means it can be used on any computer system.

XML is also a very secure language. It is designed to be secure and prevent malicious users from accessing data. XML also provides the ability to validate data, which ensures that the data is correct and consistent before it is stored or transported.

- **ZEN SERVER:**

Zen Server is a cloud-based server management system for businesses of all sizes. It is designed to help simplify server administration and increase system performance. Zen Server is a comprehensive solution that provides users with access to the latest server technology and features, including backup and recovery, monitoring and alerting, security and compliance, and much more.

Zen Server is designed to help businesses save time and money by reducing the amount of time required to manage servers. The system is simple to use, allowing users to quickly and easily manage their servers. In addition, the system is also secure, with built-in encryption and authentication features to protect data.

Zen Server also provides users with complete control over their servers. The system allows users to customize their server configurations, so that they can ensure that their servers are running optimally. In addition, the system also offers users detailed reports and analytics to help them better understand their server performance.

Zen Server is also highly scalable and can be used to manage multiple servers. This makes it ideal for businesses of all sizes, as it can be used to manage a single server or an entire server farm. The system is also highly reliable and can handle large workloads without any disruption.

- ## VMWARE:

VMWare is a virtualization and cloud computing company known for its virtualization technology, which allows for the creation of virtual machines on a physical server. It is one of the most popular virtualization technologies in the world today, and it is used by businesses of all sizes to reduce costs and increase efficiency.

VMWare enables businesses to run multiple operating systems, applications, and services on the same physical server. This allows businesses to save on hardware costs and increase their computing power. It also allows businesses to create a secure and reliable environment for their data and applications. This is done by creating virtual machines, which are isolated from each other and the underlying hardware.

VMWare also provides businesses with a number of tools and services to help manage their virtual infrastructure. These include tools for monitoring performance, capacity planning, deployment, and security. It also provides a number of cloud services, such as virtual private clouds, public clouds, and hybrid clouds. These services help businesses to reduce their costs and increase their scalability.

VMWare also provides businesses with a number of security features. These include the ability to segment their virtual infrastructure and isolate different applications and services from each other.

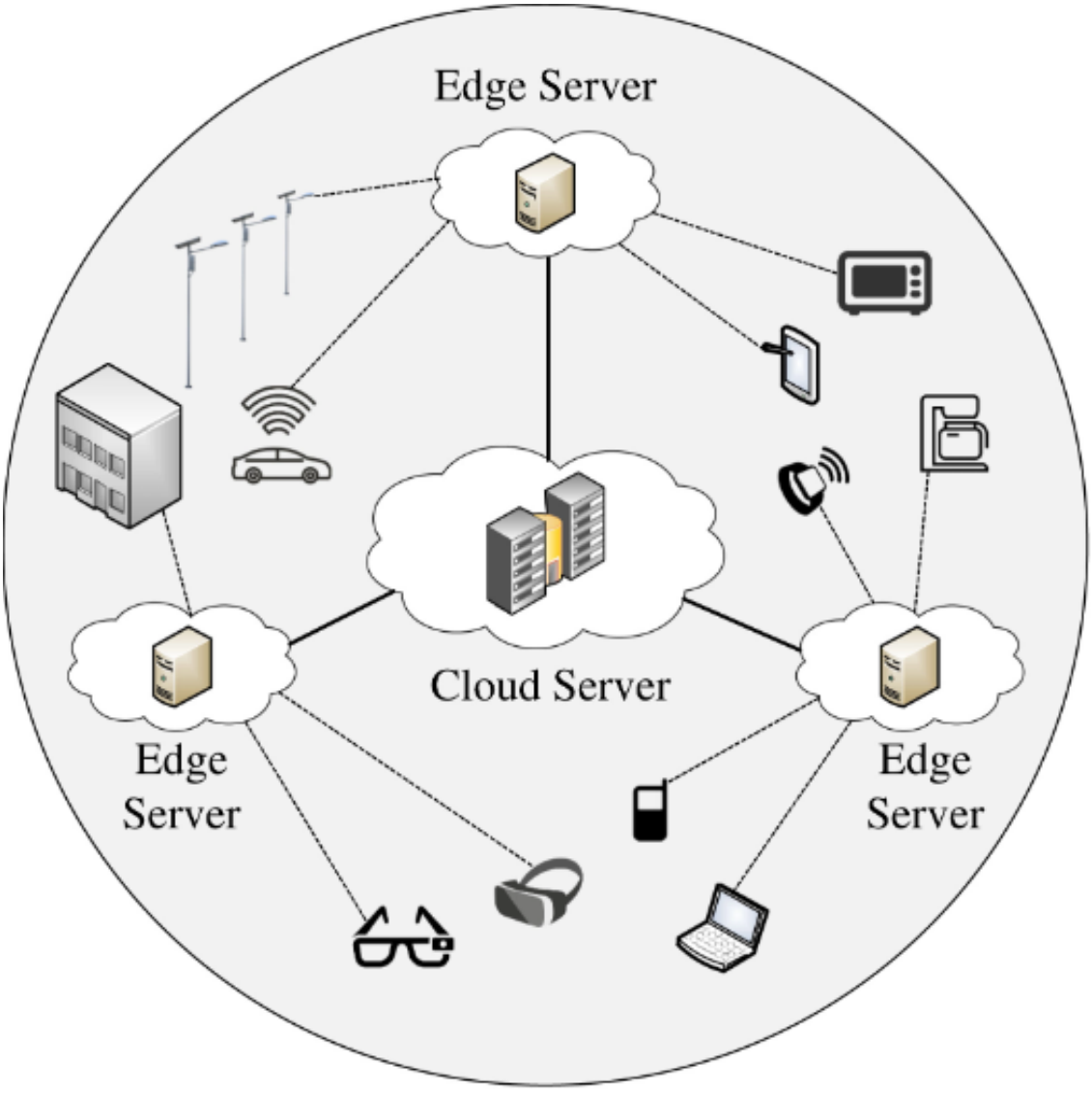
- ## ECLIPSE IDE:

Eclipse IDE is a popular Integrated Development Environment (IDE) for Java development. It is a free and open source software released under the Eclipse Public License. Eclipse is the most widely used IDE for Java development and it is used by a large number of developers around the world.

Eclipse is an extensible and customizable IDE that supports multiple programming languages, including Java, PHP, C/C++, and more. It provides powerful tools and features to help developers create and debug applications quickly and efficiently. Eclipse also has a wide range of plugins and extensions available to help developers customize their development environment.

The Eclipse IDE is designed to be easy to use and learn, and it provides a wide range of features to help developers create applications quickly and easily. It provides an integrated development environment with a code editor, a debugger, a compiler, a library manager, and a version control system. It also includes a GUI builder, a visual debugger, and a unit testing framework

Architecture of EdgeCloudSim



Project Details

System Specification:

We have installed EdgeCloudSim on a Virtual machine (VMWare+ Workstation Pro) running Ubuntu 20.04 with 2 Gb of Memory and 40 Gb of Hard Disk Space.

Installation Process:

- git clone https://github.com/CagataySonmez/EdgeCloudSim.git
- Install JAVA version 17.
- Install Eclipse IDE.

Creating New Project:

- Open Eclipse → New Project → Project name → Location → Downloaded repo (EdgeCloudSim) → Finish

Customization in Sample Code:

- Go to EdgeCloudSim/scripts/sample_app1/config/ →Edit edge_devices.xml →Added 6 new edge_devices counting to total 20 → With 6 Windows 10 machines → arch = ‘X86’→ Host with core = ‘2’ → MIPS = ‘1000’→ RAM= ‘2000’→ Storage= ‘50000’ → VMM= ‘Xen’

- Go to EdgeCloudSim/scripts/sample_app1/config/ → Edit default_config.properties → simulation_time = ‘10800’

- Go to EdgeCloudSim/scripts/sample_app1/config/ → Edit applications.xml → Added new application

Parameters of an application:

- <application name="IMAGE_PROCESSING_APP ">
- <usage_percentage>20</usage_percentage>
- <prob_cloud_selection>15</prob_cloud_selection>
- <poisson_interarrival>8</poisson_interarrival>
- <delay_sensitivity>0</delay_sensitivity>
- <active_period>18</active_period>
- <idle_period>45</idle_period>
- <data_upload>25</data_upload>
- <data_download>2000</data_download>
- <task_length>750</task_length>
- <required_core>1</required_core>
- <vm_utilization_on_edge>10</vm_utilization_on_edge>
- <vm_utilization_on_cloud>1</vm_utilization_on_cloud>
- <vm_utilization_on_mobile>0</vm_utilization_on_mobile>
- </application>

Path to open application arguments:

applications.xml
~/Desktop/EdgeCloudSim/scripts/sample_app2/config

XML File:

```xml
<?xml version="1.0"?>
<applications>
        <application name="AUGMENTED_REALITY">
                <usage_percentage>30</usage_percentage>
                <prob_cloud_selection>20</prob_cloud_selection>
                <poisson_interarrival>2</poisson_interarrival>
                <delay_sensitivity>0</delay_sensitivity>
                <active_period>40</active_period>
                <idle_period>20</idle_period>
                <data_upload>1500</data_upload>
                <data_download>25</data_download>
                <task_length>9000</task_length>
                <required_core>1</required_core>
                <vm_utilization_on_edge>6</vm_utilization_on_edge>
                <vm_utilization_on_cloud>0.6</vm_utilization_on_cloud>
                <vm_utilization_on_mobile>0</vm_utilization_on_mobile>
        </application>
        <application name="HEALTH_APP">
                <usage_percentage>20</usage_percentage>
                <prob_cloud_selection>20</prob_cloud_selection>
                <poisson_interarrival>3</poisson_interarrival>
                <delay_sensitivity>0</delay_sensitivity>
                <active_period>45</active_period>
                <idle_period>90</idle_period>
                <data_upload>20</data_upload>
                <data_download>1250</data_download>
                <task_length>3000</task_length>
                <required_core>1</required_core>
                <vm_utilization_on_edge>2</vm_utilization_on_edge>
                <vm_utilization_on_cloud>0.2</vm_utilization_on_cloud>
                <vm_utilization_on_mobile>0</vm_utilization_on_mobile>
        </application>
        <application name="HEAVY_COMP_APP">
                <usage_percentage>20</usage_percentage>
                <prob_cloud_selection>40</prob_cloud_selection>
                <poisson_interarrival>20</poisson_interarrival>
                <delay_sensitivity>0</delay_sensitivity>
                <active_period>60</active_period>
                <idle_period>120</idle_period>
                <data_upload>2500</data_upload>
                <data_download>200</data_download>
                <task_length>45000</task_length>
                <required_core>1</required_core>
                <vm_utilization_on_edge>30</vm_utilization_on_edge>
                <vm_utilization_on_cloud>3</vm_utilization_on_cloud>
                <vm_utilization_on_mobile>0</vm_utilization_on_mobile>
        </application>
```

```
48          <application name="INFOTAINMENT_APP">
49                  <usage_percentage>30</usage_percentage>
50                  <prob_cloud_selection>10</prob_cloud_selection>
51                  <poisson_interarrival>7</poisson_interarrival>
52                  <delay_sensitivity>0</delay_sensitivity>
53                  <active_period>30</active_period>
54                  <idle_period>45</idle_period>
55                  <data_upload>25</data_upload>
56                  <data_download>1000</data_download>
57                  <task_length>15000</task_length>
58                  <required_core>1</required_core>
59                  <vm_utilization_on_edge>10</vm_utilization_on_edge>
60                  <vm_utilization_on_cloud>1</vm_utilization_on_cloud>
61                  <vm_utilization_on_mobile>0</vm_utilization_on_mobile>
62          </application>
63  </applications>
```

Output

Execution Time and Result

Simulation results generate log files containing:

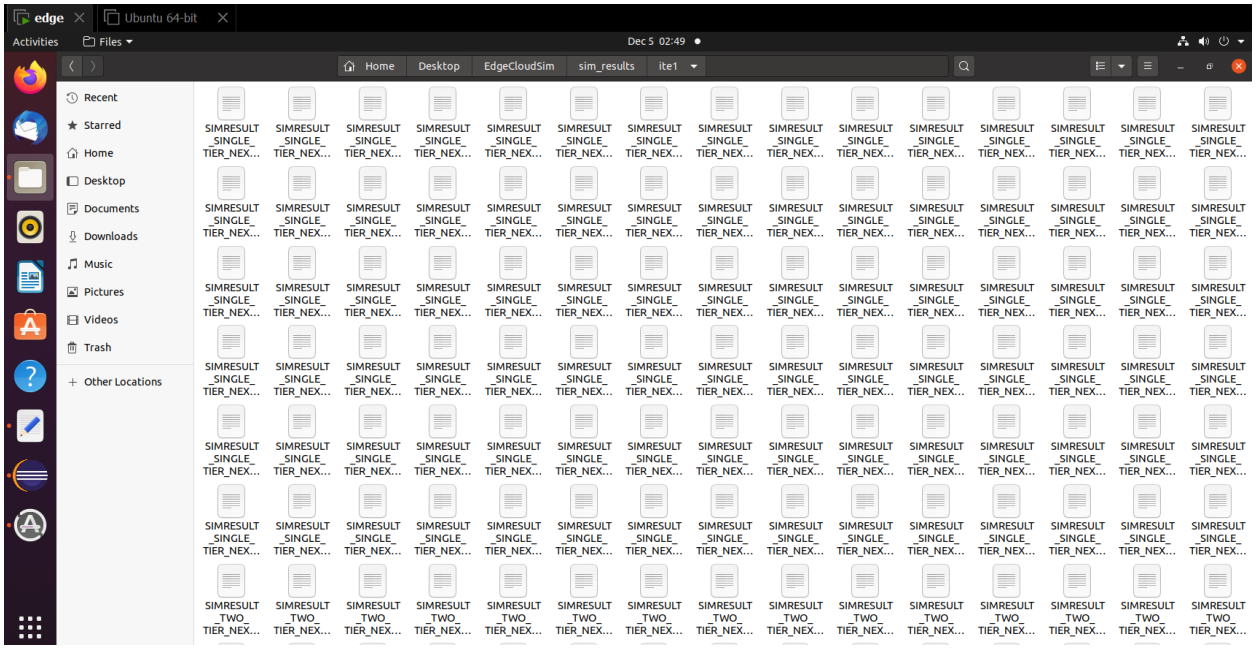
- Scenario Time
- Duration
- Iteration
- Position
- Devices
- No. of tasks (Edge/Cloud)
- Failed Tasks (Edge/Cloud)
- Completed Tasks (Edge/Cloud)
- No. of failed tasks due to VM capacity (Edge/Cloud)
- No. of failed tasks due to Mobility/Network (WLAN/MAN/WAN)
- Percentage of failed Tasks
- Avg service time
- Avg processing time
- Avg server utilization (Edge/Cloud)
- Avg cost
- Scenario finish time

The total time taken in our scenario was around 3 hrs.

Output:

```
File  Edit  Source  Refactor  Navigate  Search  Project  Run  Window  Help
Javadoc  Declaration  Console ×
MainApp [Java Application] /home/shrey/.p2/pool/plugins/org.eclipse.justj.openjdk.hotspot.jre.full.linux.x86_64_17.0.4.v20220805-1047/jre/bin/java (Dec 5, 2022, 12:59:56 AM) [pid: 2978]
# of tasks (Edge/Cloud): 14396(11420/2976)
# of failed tasks (Edge/Cloud): 121(110/11)
# of completed tasks (Edge/Cloud): 14275(11310/2965)
----------------------------------------
HEALTH_APP
# of tasks (Edge/Cloud): 700(558/142)
# of failed tasks (Edge/Cloud): 2(2/0)
# of completed tasks (Edge/Cloud): 698(556/142)
----------------------------------------
HEAVY_COMP_APP
# of tasks (Edge/Cloud): 671(419/252)
# of failed tasks (Edge/Cloud): 7(5/2)
# of completed tasks (Edge/Cloud): 664(414/250)
----------------------------------------
INFOTAINMENT_APP
# of tasks (Edge/Cloud): 3328(2855/473)
# of failed tasks (Edge/Cloud): 11(10/1)
# of completed tasks (Edge/Cloud): 3317(2845/472)
----------------------------------------
# of tasks (Edge/Cloud/Mobile): 19095(15252/3843/0)
# of failed tasks (Edge/Cloud/Mobile): 141(127/14/0)
# of completed tasks (Edge/Cloud/Mobile): 18954(15125/3829/0)
# of uncompleted tasks (Edge/Cloud/Mobile): 10(8/2/0)
# of failed tasks due to vm capacity (Edge/Cloud/Mobile): 0(0/0/0)
# of failed tasks due to Mobility/WLAN Range/Network(WLAN/MAN/WAN/GSM): 141/0/0(0/0/0/0)
percentage of failed tasks: 0.738413%
average service time: 1.544982 seconds. (on Edge: 1.762776, on Cloud: 0.684671, on Mobile: NaN)
average processing time: 1.425034 seconds. (on Edge: 1.734034, on Cloud: 0.204450, on Mobile: NaN)
average network delay: 0.119948 seconds. (LAN delay: 0.028742, MAN delay: NaN, WAN delay: 0.480221, GSM delay: NaN)
average server utilization Edge/Cloud/Mobile: 11.430363/0.249164/0.000000
average cost: 0.0$
average overhead: 0.0 ns
average QoE (for all): 0.0%
average QoE (for executed): 0.0%
Scenario finished at 05/12/2022 01:01:10. It took 10 Seconds
----------------------------------------------------------------------
Scenario started at 05/12/2022 01:01:10
Scenario: SINGLE_TIER - Policy: NEXT_FIT - #iteration: 1
Duration: 0.5 hour(s) - Poisson: 5.0 - #devices: 300
Creating tasks...Done,
Creating device locations...Done.
SimManager is starting...Done.
..
```

Result log files:



Conclusion

- ***Edge computing for both large and small enterprises:*** Overall, edge computing is geared toward larger enterprises, but that doesn't mean there isn't a need for it when it comes to smaller companies. Covid brought remote work, and remote work brought distributed workers. Employees are moving around and working across the country. Businesses need to realize how much of a necessity edge computing is to minimize latency and increase productivity. Edge is the answer.

- ***Customer experience:*** Everything businesses do always leads back to creating a positive customer experience, so they'll continue coming back. We'll begin to see edge used to create better customer outcomes. The primary benefit of the edge is the ability to increase speeds. This alone can create a better customer experience because consumers want instant gratification, not clunky, inefficient experiences. But the benefits don't stop at speed. Edge compute can also create personalization by quickly processing data. As marketers focus on more data-centric strategies, edge computing can bring the information closer to the source to drive faster analysis.

- ***The rise of IoT devices:*** In the future, we'll see an increased push and adoption of IoT systems, especially as 5G becomes more widely available. The once futuristic smart homes and self-driving cars that we've always imagined will be made possible with edge computing. Self-driving cars, for example, need the quick data processing that comes with edge. If there's a delay while the car is driving down the street, the results could be deadly. But IoT is more than just self-driving cars or smart refrigerators. IoT can also be used in key industries like healthcare and manufacturing. For example, remote monitoring using IoT devices can allow for ongoing visibility into patients' healthcare records. This includes things like sending alerts to patients and doctors when vitals are out of range. The options are endless when IoT pairs with edge computing.

- ***AR and VR use cases:*** Augmented Reality (AR) and Virtual Reality (VR) have been around for some time, but as enterprises adopt this technology more, edge computing will be imperative. One of the biggest uses of AR/VR for businesses is the ability for potential customers to experience a product or service before they actually purchase it. However, to have a seamless experience, the data needs to be processed close to the VR device. AR/VR devices can be used beyond client-facing use cases as well. They also allow colleagues to participate in real-time sharing of work, enable remote collaboration or help with complex training, all of which need the speed of edge processing to operate well fully. And those are just the current capabilities. We'll continue to see more emerging use cases of AR/VR as it expands, including the Metaverse. As the Metaverse becomes prevalent among consumers and businesses, it too will need the power of edge computing.

- ***Security upgrades:*** Security is a concern every company knows too well. In 2021, cyberattacks increased 50% compared to 2020, and we're sure to see that number continue to grow. Edge computing makes cybersecurity more difficult. As more businesses begin utilizing edge compute, more edge devices will be put in place, opening many more entry points for bad actors. This forces a greater need for security talent who can continuously test, update and patch any security systems in place while also monitoring all devices to ensure any licensing or warranties are up to date. The bottom line is that there needs to be a team dedicated to monitoring each edge compute point, so no security breaches happen.

References

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- https://stlpartners.com/articles/edge-computing/mobile-edge-computing/
- https://app.pluralsight.com/course-player?clipId=a957eaf3-07a1-46f6-a02d-dc907fdf0e12&_gl=1*mdid75*_ga*MTk0NTkyNC4xNjcwMDgyNjcw*_ga_525M96C6Y1*MTY3MDA4MjY3MC4xLjAuMTY3MDA4MjY3MC4wLjAuMA