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Internet of Things

Unit 3: IoT Data Analytics and Edge Computing

NCI | Lárionad Néal-Inniúlachta Cloud Competency Centre

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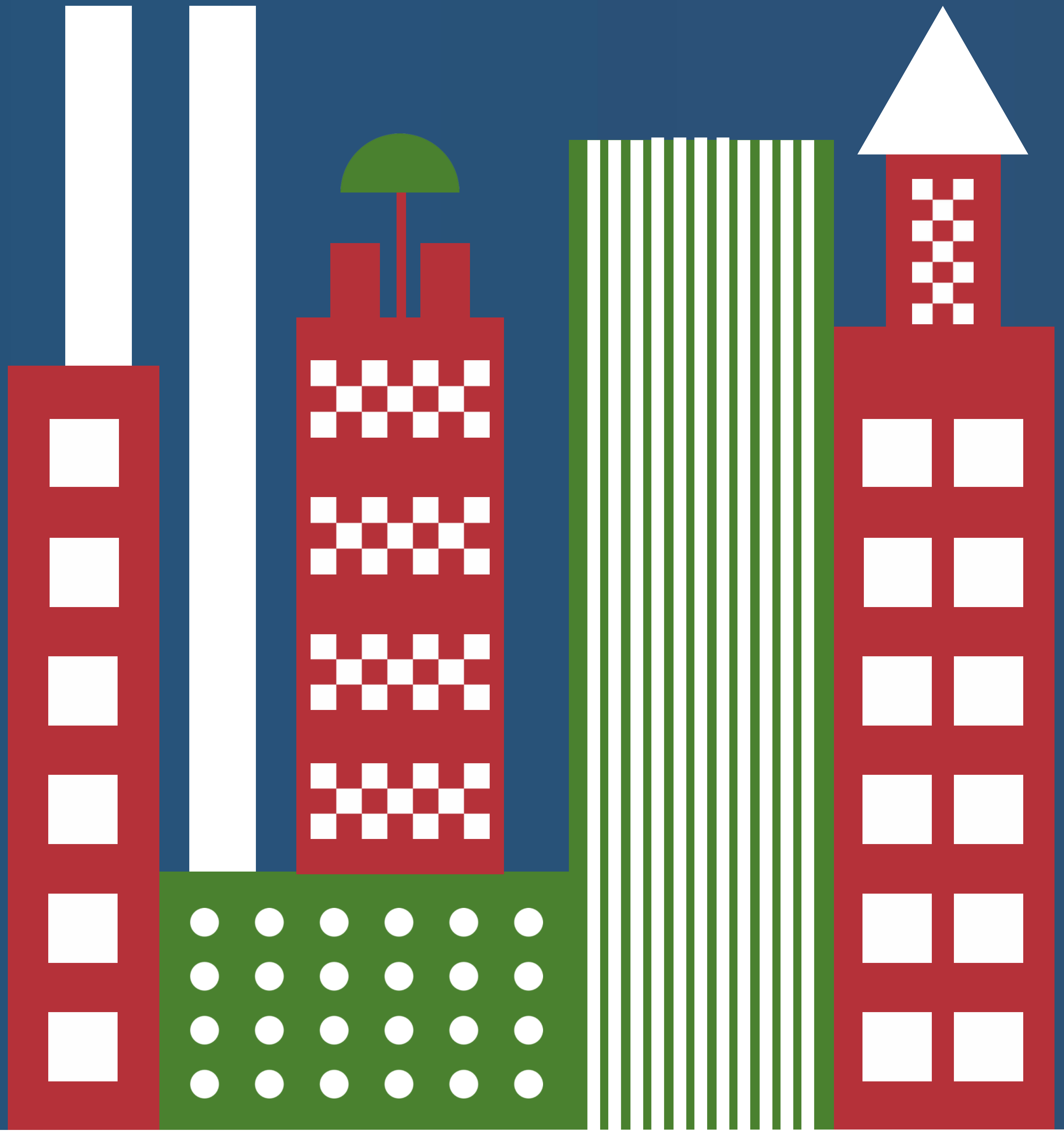

Unit 3: IoT Data Analytics and Edge Computing

- IoT Data Analytics
- IoT Edge Computing

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What is IoT Data Analytics

IoT Data Analytics is the use of data that has been collected from IoT devices for processing and analytics purposes. This data is then used to provide actionable insights which can support decision-making and improve business operations.

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IoT Data Lifecycle

- Data Creation
- Data Transmission
- Data Preprocessing
- Data Storage
- Data Processing
- Data Retention
- Data Archive
- Data Purging/Cleansing
- Data Re-use/Re-Purpose

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Data Collection from IoT Sensors and Devices

IoT Sensors and Devices collect huge amounts of raw data. This can include data such as humidity, temperature, pressure, motion and sound readings.

Methods of Collection:

- Direct Collection from Physical Devices
- Wireless Communication
- Aggregation Techniques
- Mobile Terminals
- Edge Processing

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Data Processing Challenges

- Scalability
- Data Volume
- Latency
- Heterogeneity
- Data Quality and Veracity
- Data Security and Privacy
- Optimisation
- System Availability
- Data Reduction
- Analytics Latency

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Why is Data Storage Important in IoT?

- Massive Data Volume
- Accessibility and Usability
- Heterogeneity
- Analytics
- Scalability and Flexibility
- Data Security and Privacy
- Real-Time Processing

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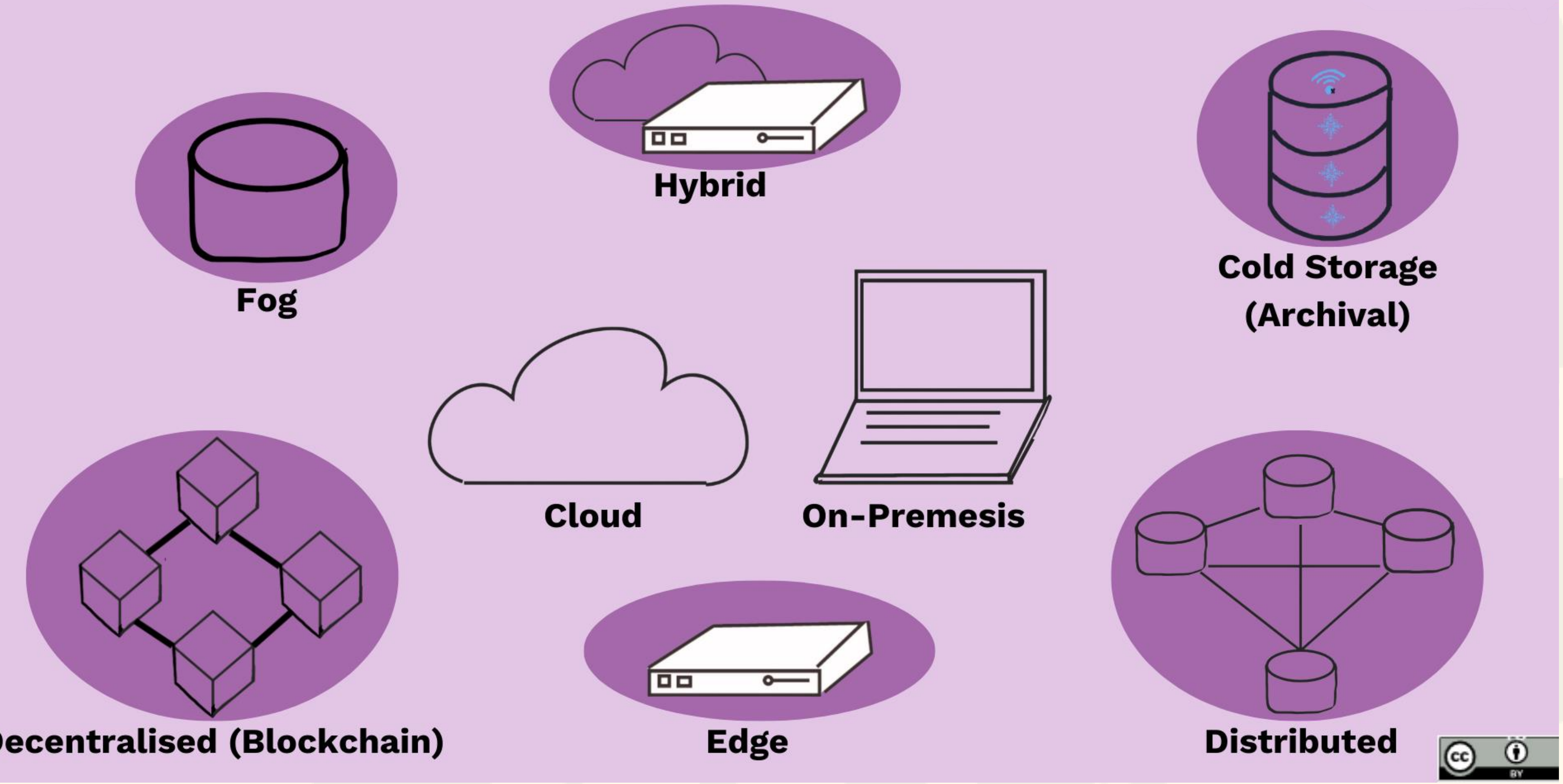
Data Storage for IoT



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Considerations For IoT Data Analytics-Analytics Types and Techniques

Descriptive Analytics

Predictive Analytics

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Descriptive and Predictive Analytics

Descriptive Analytics

Descriptive analytics is all about understanding historical data—it answers the question, "what has happened or what is happening?". It helps identify patterns, trends, and past events, making it useful for spotting business opportunities and challenges.
For example, a company could use descriptive analytics to track the number of defective products over time and pinpoint the reasons behind those defects. This insight can then be used to improve quality control and reduce waste, ultimately making operations more efficient.

Predictive Analytics

Predictive analytics is all about anticipating future outcomes—it answers the question, "what will happen and why?". By using statistical models and machine learning, it helps identify potential issues before they arise, allowing businesses to take proactive measures.
For example, predictive analytics can forecast inventory levels, anticipated demand, and potential equipment failures, helping companies optimise resources and prevent disruptions. It leverages technologies like data mining, text analysis, and web analytics to provide accurate, data-driven predictions about future conditions.

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Considerations For IoT Data Analytics- Data Characteristics

The 10 V's:

- Volume
- Velocity
- Variety
- Veracity
- Value
- Variability
- Volatility
- Validity
- Visualisation
- Vulnerability

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Applications of IoT Data Analytics

SMART TRANSPORTATION

SMART HEALTHCARE

SMART GRIDS

SMART CITIES

AIR QUALITY MANAGEMENT

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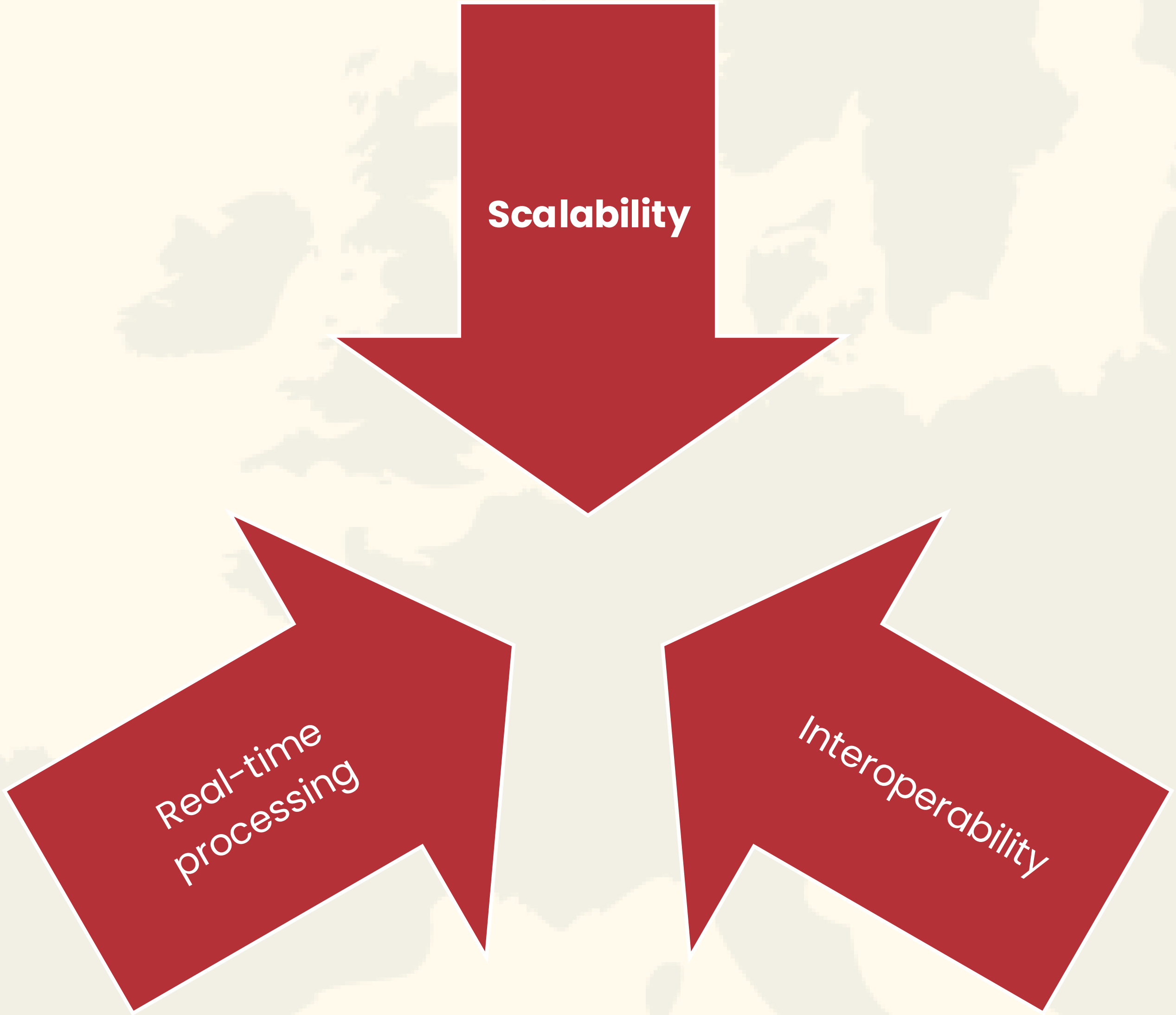
Considerations For IoT Data Analytics- System and Infrastructure



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Considerations For IoT Data Analytics- Business Needs

- Business Experience
- Identify Market Value Opportunities
- Recognise Issues
- Alignment with technical talent and functional managers
- Disruptive to be innovative

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Considerations For IoT Data Analytics- Data Lifecycle Management

Due to the vast amounts of heterogenous, high-velocity data collected by IoT devices, DLM is a critical consideration for IoT Data Analytics.

DLM provides a framework to manage data from its creation, though to it's deletion and ensures that the data is available, usable and secure for analytics purposes. This allows for organisations to extract valuable insights which helps them to optimise their operational processes and make informed decisions.

Without an optimal DLM, organisations can become overwhelmed with IoT data due to the volume and complexity and can miss out on the opportunities and insights this data could provide from meaningful analytics.

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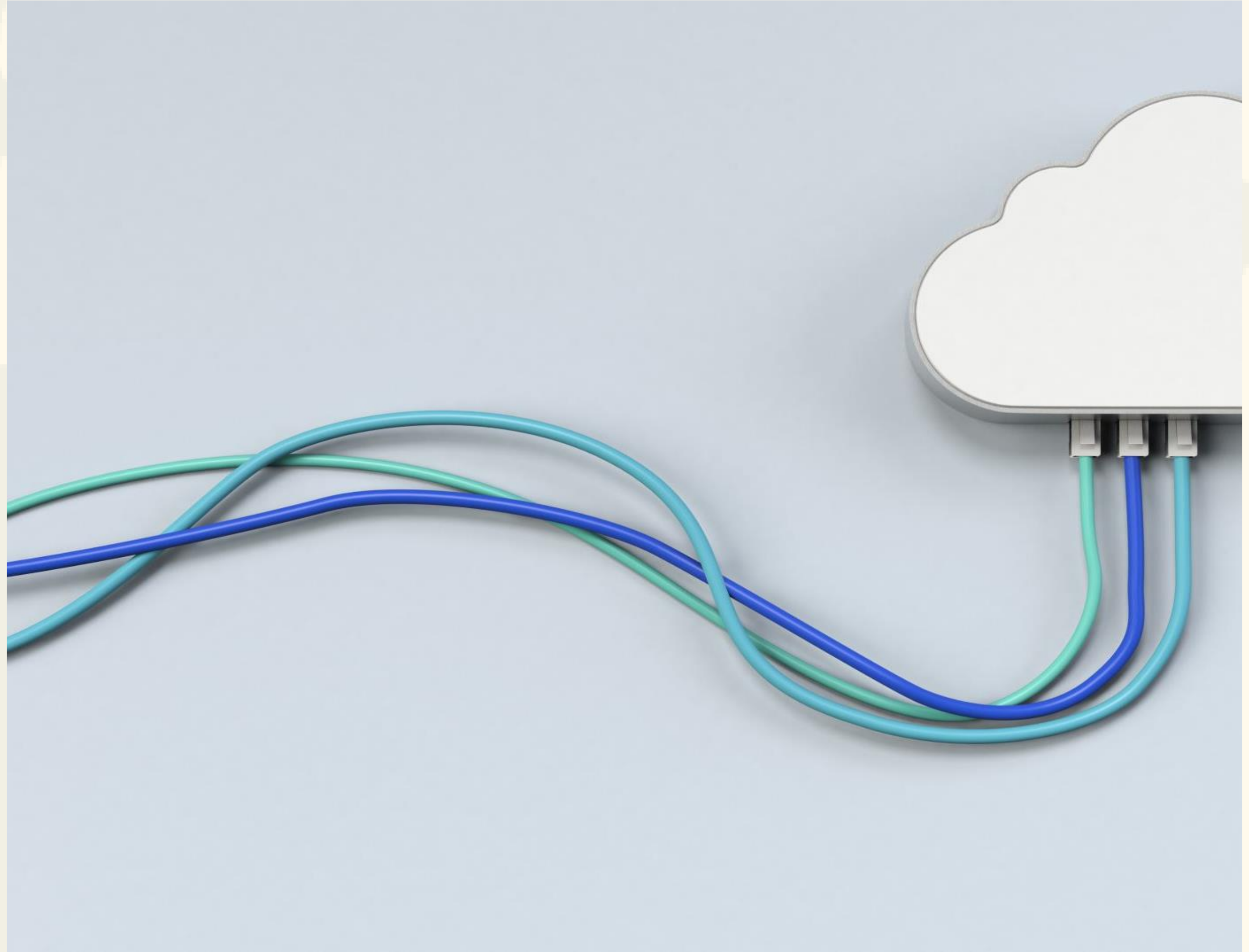
Considerations For IoT Data Analytics-Privacy

The data collected from IoT devices can often be personal or sensitive data, for example health, behaviour, and location. Because of this, intimate information about an individual can be extracted from this data, this makes it a target for security breaches and unauthorized access along with risks of general leaks.

Robust privacy measures are essential in the collection, analysis and storage of IoT data to prevent data leakes, identify theft and other privacy violations.



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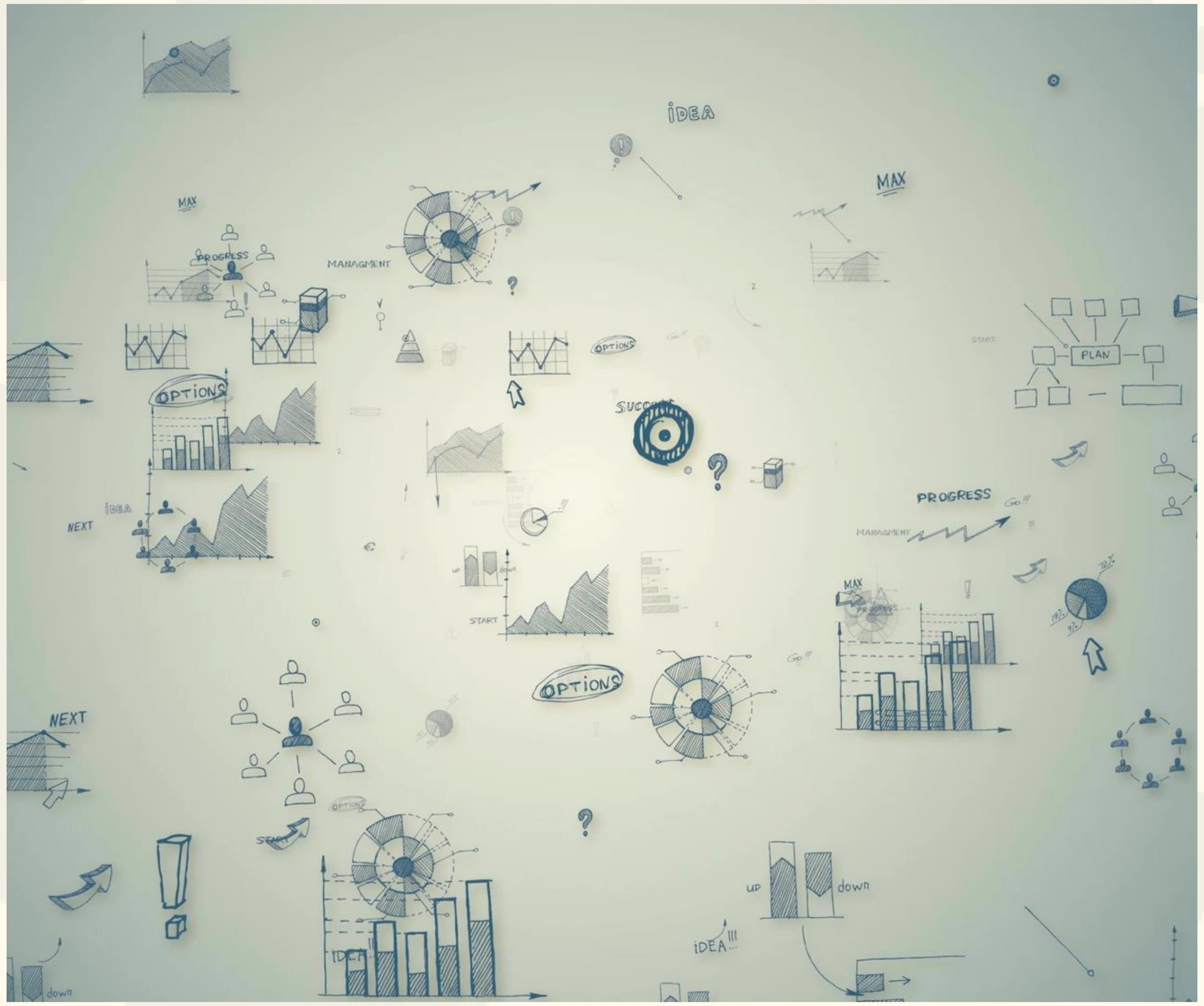
Considerations For IoT Data Analytics- Visualisation

Visualisation plays a crucial role in IoT Data Analytics because the sheer volume and complexity of IoT data can be overwhelming without a clear way to interpret it. Using charts, graphs, dashboards, and other visual formats makes it easier to spot patterns, trends, and anomalies- insights that would be difficult to extract from raw data alone.

This not only makes data more accessible but also supports faster and more informed decision-making. While visualising IoT data comes with challenges, particularly given its scale and variety, effective visualisation is key to unlocking its true value and turning data into actionable insights.



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Considerations For IoT Data Analytics- Security

Security is a key concern in IoT Data Analytics because of the sheer volume and sensitivity of data generated by a wide range of connected devices. With so many interconnected systems, there are multiple potential entry points for cyber threats, which can lead to data breaches, unauthorised access, and disruptions to critical services.

To build trust in IoT technologies, ensure compliance with data privacy regulations, and fully harness the benefits of data-driven insights, security needs to be embedded at every stage- from devices and networks to analytics platforms. The diversity of IoT devices, along with their limited computing resources, adds an extra challenge, meaning security measures often need to be lightweight yet effective.

A strong security framework across the entire IoT data lifecycle isn't just important- it's essential for ensuring the safe, responsible, and scalable deployment of IoT Data Analytics.

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Key Tools and Platforms for Data Analytics

- Microsoft Azure IoT Analytics
- AWS IoT Analytics
- IBM Watson IoT Platform
- Google Cloud IoT Core and Cloud IoT Analytics
- ThingSpeak
- C3.ai
- Predix
- Ubidots
- Particle
- Kaa IoT Platform

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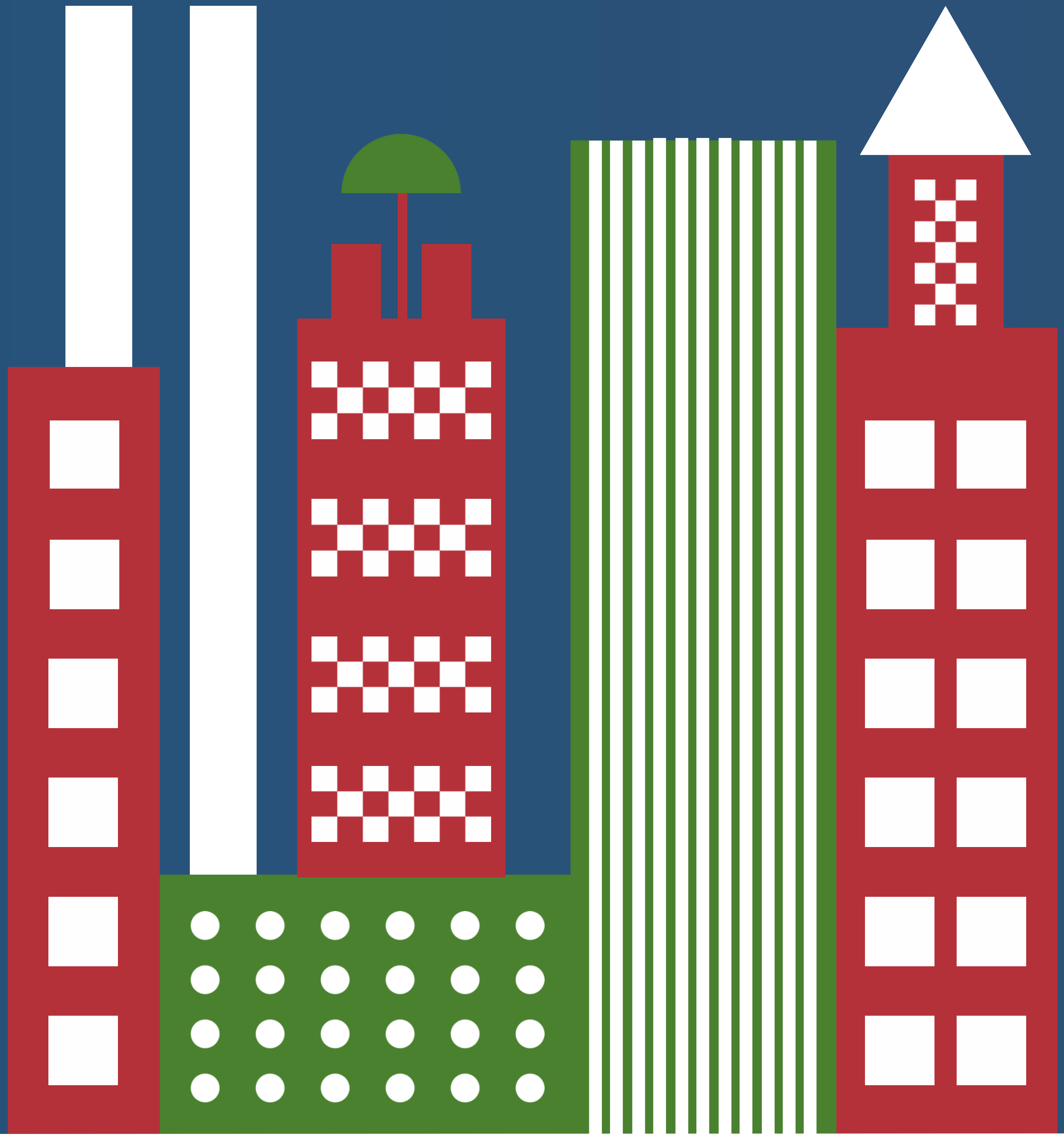

IoT Edge Computing

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Refresh: Distinction between Edge and Fog

EDGE

FOG

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Cloud and Edge Integration in IoT Networking

The integration of cloud and edge computing enhances IoT performance by balancing centralised and decentralised data processing.

How It Works:

Edge Computing: Processes data locally to reduce latency and bandwidth usage (e.g., self-driving cars processing sensor data in real-time).

Cloud Computing: Provides large-scale data storage and analytics.

Emerging Trends:

Fog Computing: An intermediary layer between edge and cloud, reducing the burden on both.

AI in Edge Networks: Optimising network performance through machine learning.

Example: A smart grid using edge devices for local power management and cloud platforms for predictive maintenance analytics.

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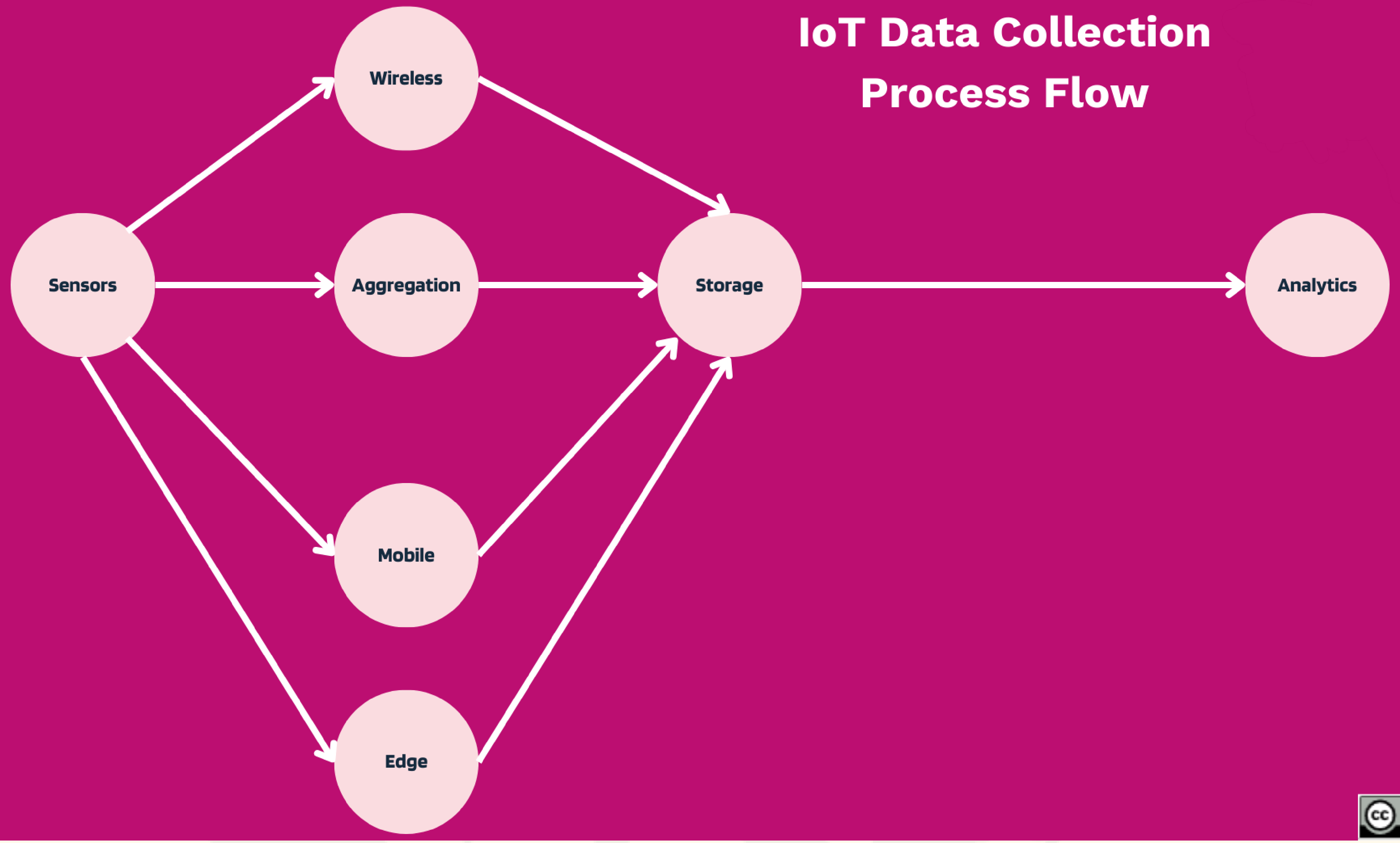
IoT Data Collection Process Flow



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IoT Storage Types Overview

Storage Type	Key Benefit	Key Challenge	Real-World Example
Cloud Storage	Provides scalable and centralised data storage, ensuring seamless access to IoT data across multiple locations.	High latency & bandwidth costs	**TFL Smart City Traffic Management**
On-Premises Storage	Ensures greater control over sensitive data and compliance with regulatory requirements.	Scalability & maintenance costs	**Mayo Clinic & Google Cloud Partnership (Source)**
Fog Storage	Enables real-time processing and lower latency for critical IoT applications like healthcare monitoring.	Security risks at edge nodes	**Fog Computing in Healthcare IoT**
Hybrid Storage	Optimises real-time data processing at the edge while enabling scalable cloud storage for long-term insights.	Balancing cost & integration complexity	**IT Service Management**
Cold Storage	Provides cost-effective long-term archival storage for regulatory and historical data.	Slow retrieval times & compliance risks	**AWA- Long Term Data Preservation**
Distributed Storage	Improves fault tolerance, availability, and scalability by distributing data across multiple nodes.	High implementation costs & data consistency issues	**US Signal- Ceph Distributed Storage**
Edge Storage	Reduces latency and bandwidth usage by storing and processing data near IoT devices.	Limited capacity & security vulnerabilities	**Industrial IoT Predictive Maintenance (Source)**
Decentralised Storage	Enhances security, transparency, and trust by storing IoT data across decentralised blockchain nodes.	Deployment complexity & scalability costs	**IBM Food Trust**

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Edge Computing and IoT

Edge Computing has become a popular and growing solution to some of the challenges that can come with IoT.

Edge computing enables improvements in:

- High Latency
- Network Congestion
- Bandwidth Demands

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How?

Edge computing helps businesses tackle these challenges by:

Reducing latency and improving real-time response.

Conserving network bandwidth.

Extending battery life of resource-constrained IoT devices.

Enabling new, advanced IoT applications.

Complementing cloud computing, not replacing it.

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Reducing Latency and Improving Response Time

Edge computing processes data locally.

Reduces transmission delays between IoT devices and processing units.

Enables real-time responses for:

Autonomous vehicles	Smart manufacturing	Real-time monitoring systems

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Conserving Bandwidth

- Processes and filters data at the edge before cloud transmission.
- Reduces data transfer volumes and network congestion.
- Lowers operational costs for bandwidth use.

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Extending IoT Device Battery Life

Offloads heavy computation to powerful edge nodes.

Reduces communication overhead for devices.

Extends the operational lifetime of battery-powered sensors and devices.

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Enabling New IoT Applications

Low latency and local processing enable:

- Smart cities
- Industrial automation
- Smart grids
- Augmented reality
- Autonomous systems

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Working with the Cloud

Edge	Edge computing complements cloud computing.
Cloud	Cloud handles big data analytics and large-scale storage.
Edge	Edge focuses on immediate processing and real-time decision-making.

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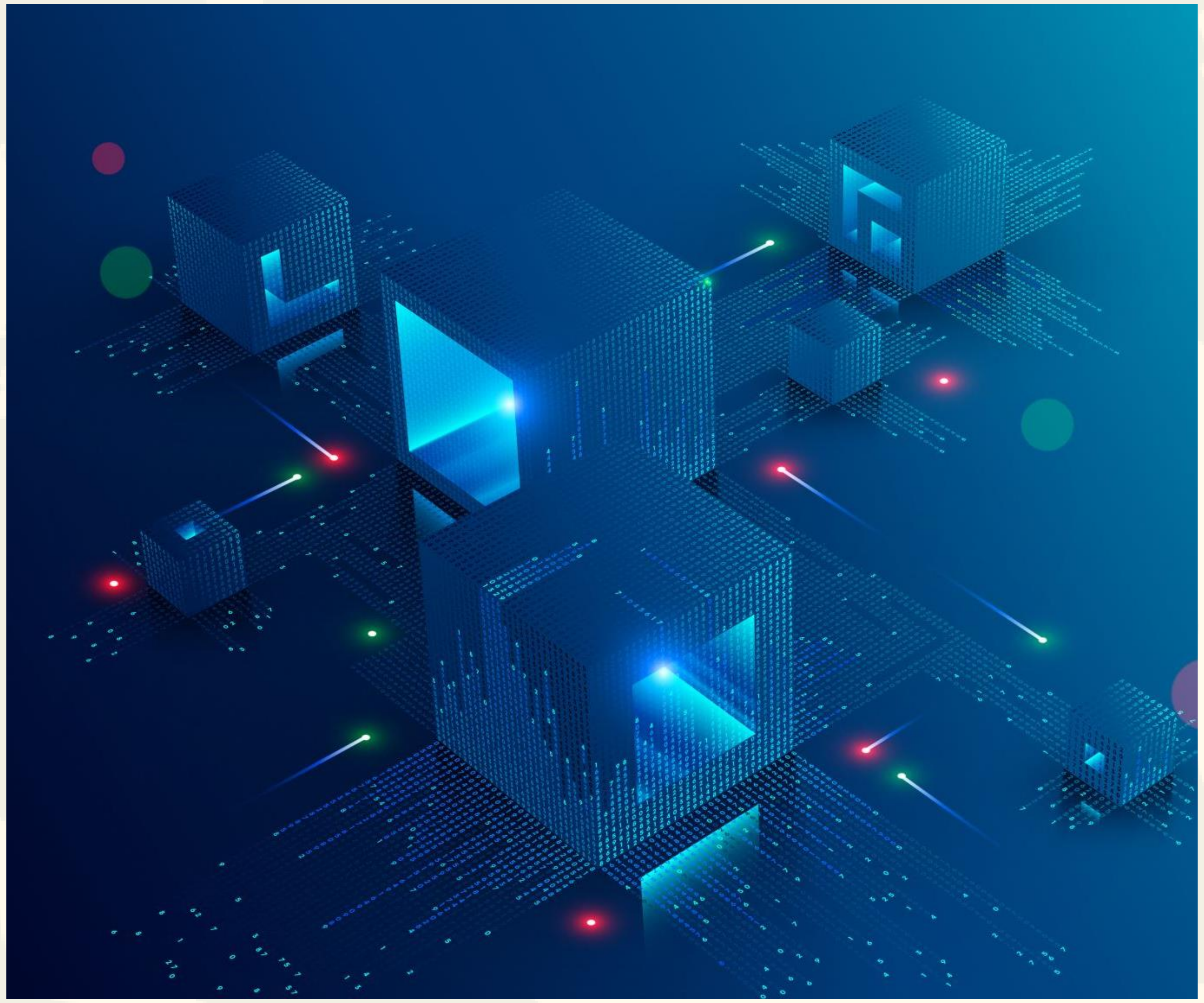
Edge Computing-based IoT

- The integration of IoT and edge computing is referred to as edge computing-based IoT.
- Leverages the strengths of both paradigms.
- Creates efficient, responsive, and scalable IoT systems.



Challenges

- Security Risks
- Complexity of Management
- Interoperability Issues
- Resource Constraints
- Data Integrity

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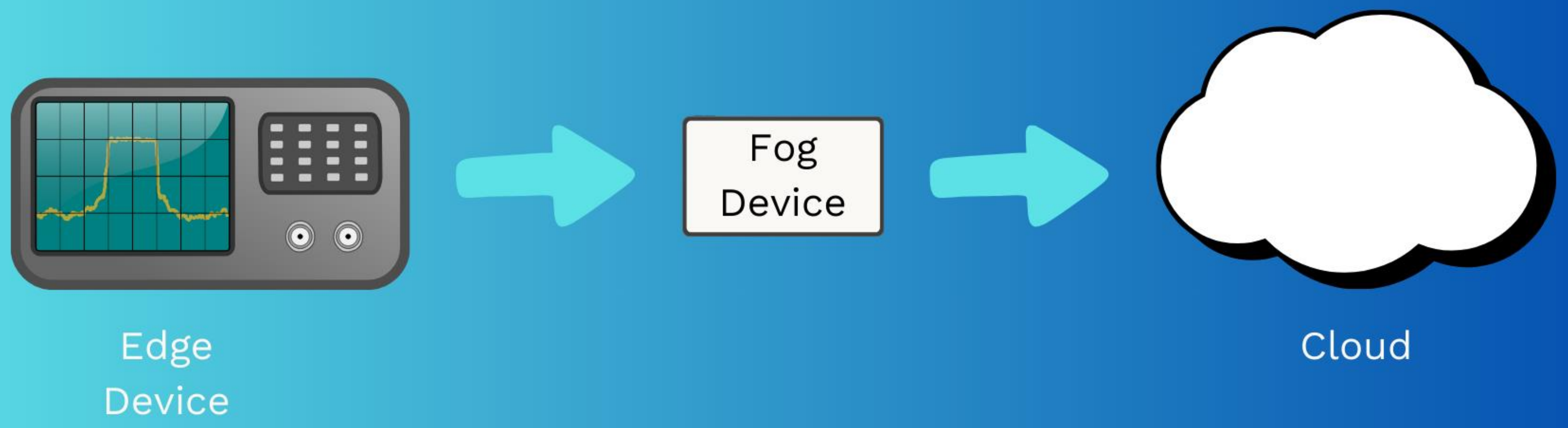
Fog Computing



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Why Fog Computing?

With the vast amount of data being uploaded to the cloud, this can cause latency, bandwidth and privacy issues. Adding fog nodes to the network can help overcome these issues.

Fog Computing can reduce:

Traffic loads	Energy consumption	Cloud Processing Costs	Improve Privacy

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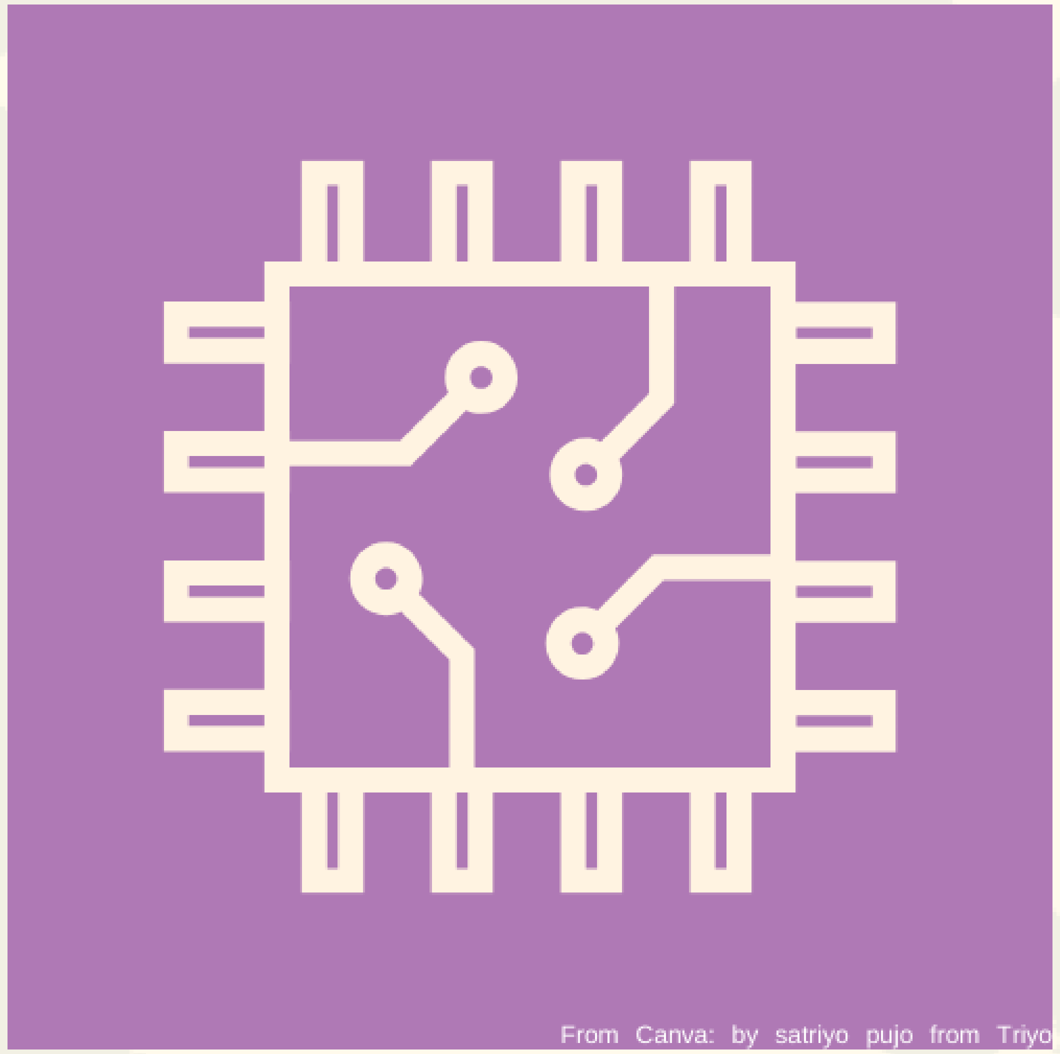
SCALE

According to the OpenFog Consortium (2017) the benefits of Fog Computing add up to SCALE:

- **S**ecurity: the processing of sensitive data can occur locally, security measures can also be enforced through multiple points
- **C**ognition: Fog computing enables the ability to embed intelligence within fog nodes, which allows them to make autonomous decisions based on real-time data and client-specific needs. This makes fog computing highly client-centric, as fog nodes can adjust their settings and behaviour to meet the unique requirements of each application or user.
- **A**gility: The programmability and scalability of fog computing enable rapid adaptation and flexibility, allowing fog systems to quickly respond to changing conditions and user needs. This agility can foster continuous innovation, which supports the development and deployment of new services and applications.
- **L**atency: Fog improves latency by processing data closer to where it is generated
- **E**fficiency: Fog computing enhances efficiency by utilising local resources such as storage and computing power at fog nodes, which reduces the need to send large amounts of data to the cloud. This decentralised approach optimises bandwidth usage and lowers energy consumption, as data is processed closer to its source. Additionally, fog nodes dynamically allocate resources based on demand, which can ensure that systems run more efficiently and cost-effectively.



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Fog and Cloud Deployment Scenarios Across a Multi-Layered System

Organisation Systems				
Business Support	Fog	Cloud	Cloud	Cloud
Operational Support	Fog	Fog	Cloud	Cloud
Monitoring and Control	Fog	Fog	Fog	Cloud
Device Sensors and Actuators				

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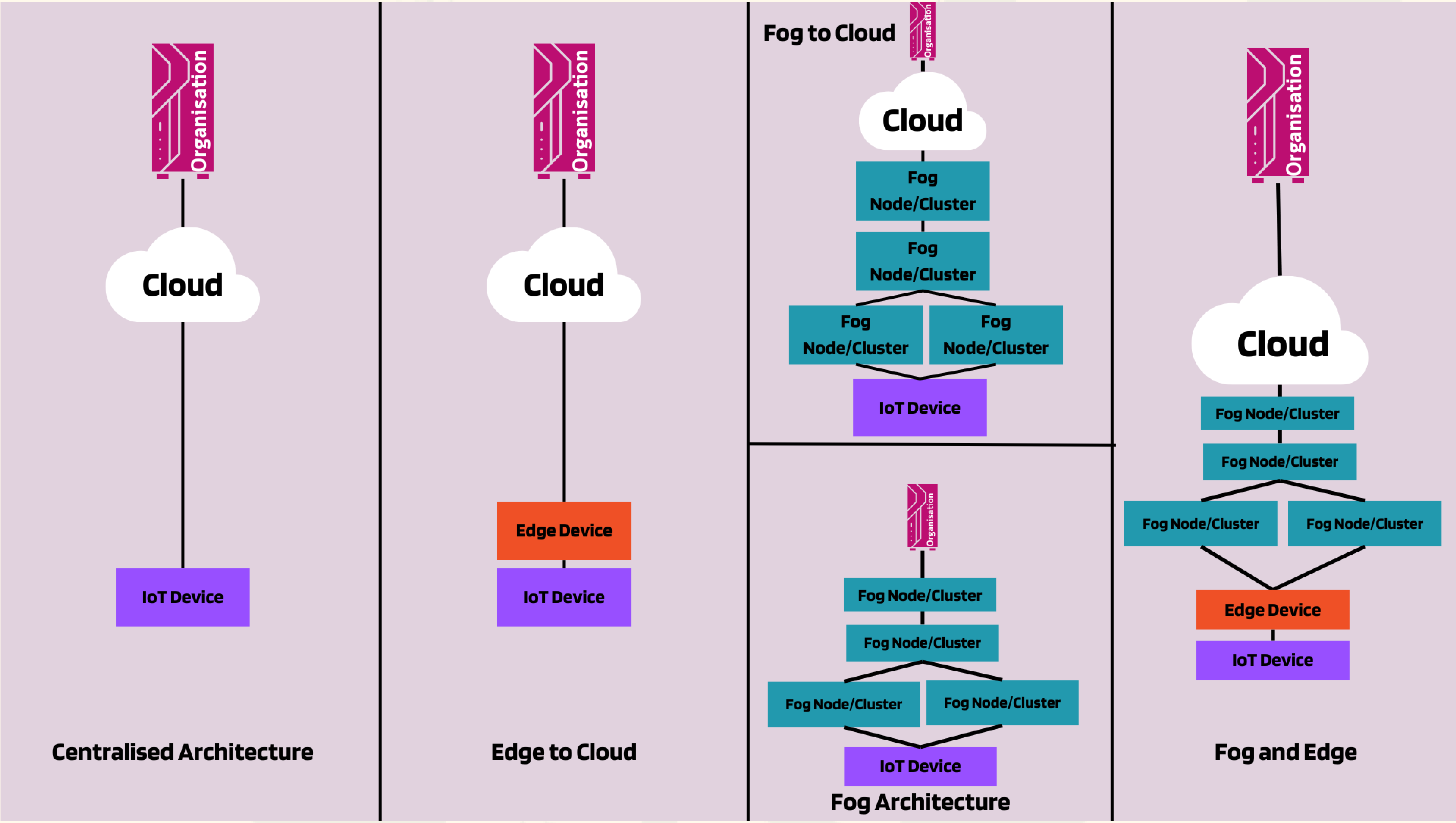

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How does fog computing help business tackle challenges?

- Improving efficiency and Performance
- Reducing costs of Cloud Processing
- Enhances Data Security and Privacy
- Allows for greater business Agility and Flexibility
- Offers new Business Opportunities and Revenue Streams
- Allows for better management of IoT Data Overload
- Improved Reliability and Resilience

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Edge, Fog, and Cloud Computing for Business Decision-

Factor	Edge Computing	Fog Computing	Cloud Computing
Definition	Processes data locally, close to IoT devices.	Acts as an intermediary layer between Edge and Cloud.	Processes data in a centralised remote cloud.
Latency	Ultra-low latency (real-time decision-making).	Low latency (faster than Cloud but slower than Edge).	Higher latency due to data transmission.
Scalability	Limited (depends on device capability).	Moderate (supports regional scalability).	High scalability (centralised infrastructure).
Cost Efficiency	Higher initial costs (investment in Edge hardware).	Moderate (requires Fog nodes but reduces cloud usage).	Lower initial costs, but higher long-term data processing costs.
Data Privacy & Security	High (keeps sensitive data on-premise).	Moderate (aggregates data before sending to cloud).	Lower (data stored in cloud, increasing compliance risks).
Computational Power	Limited (constrained by device processing power).	Higher than Edge (Fog nodes can handle moderate processing).	Unlimited (uses powerful cloud data centres).
Data Transfer Costs	Low (minimal cloud dependency).	Moderate (some data still sent to cloud).	High (constant data transmission costs).
Reliability	High (operates even without internet).	Moderate (relies on Fog node availability).	Lower (service disruptions impact accessibility).
Best Use Cases	Real-time analytics, autonomous systems, healthcare monitoring, smart manufacturing.	Smart cities, industrial IoT, regional data aggregation.	Long-term data storage, AI model training, enterprise cloud applications.

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References and Further Reading

- Ara, A. and Ara, A. (2018). Case study: Integrating IoT, streaming analytics and machine learning to improve intelligent diabetes management system. [online] ieeexplore.ieee.org. Available at: https://ieeexplore.ieee.org/abstract/document/8390043.
- Atzori, L., Iera, A. and Morabito, G. (2010). The internet of things: A survey. Computer Networks, 54(15), pp. 2787–2805.
- AWS (2018). AWS IoT Analytics Overview - Amazon Web Services. [online] Amazon Web Services, Inc. Available at: https://aws.amazon.com/iot-analytics/.
- Bhatia, J., Italiya, K., Jadeja, K., Kumhar, M., Chauhan, U., Tanwar, S., Bhavsar, M., Sharma, R., Manea, D.L., Verdes, M. and Raboaca, M.S. (2023). An Overview of Fog Data Analytics for IoT Applications. Sensors, [online] 23(1), p.199. doi:https://doi.org/10.3390/s23010199.
- Chakraborty, I. (2017). Introducing Google Cloud IoT Core: for securely connecting and managing IoT devices at scale. [online] Google Cloud Blog. Available at: https://cloud.google.com/blog/products/gcp/introducing-google-cloud-iot-core-for-securely-connecting-and-managing-iot-devices-at-scale.
- CISCO. (2016). Cisco Global Cloud Index: Forecast and Methodology, 2016–2021. Available: https://www.cisco.com/c/en/us/solutions/collateral/service-provider/global-cloud-index-gci/white-paper-c11-738085.html.
- Dave, D.M. and Mehta, R. (2024). Edge Computing: Use Cases in Manufacturing and IoT. International Journal of Global Innovations and Solutions (IJGIS). [online] doi:https://doi.org/10.21428/e90189c8.91411aea.
- Elijah, O., Rahman, T.A., Orikumhi, I., Leow, C.Y. and Hindia, M.N. (2018). An Overview of Internet of Things (IoT) and Data Analytics in Agriculture: Benefits and Challenges. IEEE Internet of Things Journal, 5(5), pp.3758–3773. doi:https://doi.org/10.1109/jiot.2018.2844296.

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References and Further Reading

- Fawzy, D., Moussa, S.M. and Badr, N.L. (2022). The Internet of Things and Architectures of Big Data Analytics: Challenges of Intersection at Different Domains. IEEE Access, 10, pp.4969–4992. doi:https://doi.org/10.1109/access.2022.3140409.
- Ghosh, A. and Grolinger, K. (2021). Edge-Cloud Computing for Internet of Things Data Analytics: Embedding Intelligence in the Edge With Deep Learning. IEEE TRANSACTIONS ON INDUSTRIAL INFORMATICS, 17(3). doi:https://doi.org/10.1109/TII.2020.3008711.
- Greene, S. M., Ahmed, M., Chua, P. S. and Grossmann, C. (eds.) (2022). Sharing Health Data: The Why, the Will, and the Way Forward. National Academies Press.
- Gulia, P. and Chahal, A. (2020). Big Data Analytics for IoT. [online] Ssrn.com. Available at: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3657061 [Accessed 19 Feb. 2025].
- Hu, W., Gao, Y., Ha, K., Wang, J., Amos, B., Chen, Z., Pillai, P. and Satyanarayanan, M. (2016). Quantifying the impact of edge computing on mobile applications. In Proceedings of the 7th ACM SIGOPS Asia-Pacific Workshop on Systems, pp. 1–8. Hong Kong, 4–5 August 2016.
- Huang, N., Zhu, J., Guo, C., Cheng, S. and Li, X. (2021). A novel hash chain-based data availability monitoring method for off-site Disaster Recovery Architecture. Journal of Circuits, Systems and Computers, 30(16).
- IBM (2024). IBM Watson IoT Platform Lite. [online] Ibm.com. Available at: https://www.ibm.com/docs/en/watson-iot-platform?topic=product-overview-features .
- Indrakumari, R., Poongodi, T., Suresh, P. and Balamurugan, B. (2020). Chapter Seven - The growing role of integrated and insightful big and real-time data analytics platforms. [online] ScienceDirect. Available at: https://www.sciencedirect.com/science/article/pii/S006524581930052X.

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References and Further Reading

- Kumar, S., Dube, D., K, K.P. and Aithal, P.S. (2020). Emerging Concept of Tech-Business-Analytics an Intersection of IoT & Data Analytics and its Applications on Predictive Business Decisions. SSRN Electronic Journal. doi:https://doi.org/10.2139/ssrn.3721497.
- Marjani, M., Nasaruddin, F., Gani, A., Karim, A., Abaker, I., Hashem, T., Siddiqa, A. and Yaqoob, I. (2017a). Big IoT Data Analytics: Architecture, Opportunities, and Open Research Challenges. IEEE. doi:https://doi.org/10.1109/ACCESS.2017.2689040.
- Mehdipour, F., Noori, H. and Javadi, B. (2016). Energy-efficient big data analytics in datacenters. In Advances in Computers, 100, pp. 59–101. Elsevier.
- Microsoft (n.d.). Azure IoT – Internet of Things Platform | Microsoft Azure. [online] azure.microsoft.com. Available at: https://azure.microsoft.com/en-us/solutions/iot.
- Nguyen, D.C., Cheng, P., Ding, M., Lopez-Perez, D., Pathirana, P.N., Li, J., Seneviratne, A., Li, Y. and Poor, H.V. (2021). Enabling AI in Future Wireless Networks: A Data Life Cycle Perspective. IEEE Communications Surveys & Tutorials, [online] 23(1), pp.553–595. doi:https://doi.org/10.1109/COMST.2020.3024783.
- Nick, G. (2022). How Many IoT Devices Are There In 2022? More Than Ever! Available online: https://techjury.net/blog/how-many-iot-devices-are-there/.
- Rahul, K. and Banyal, R.K. (2020). Data Life Cycle Management in Big Data Analytics. Procedia Computer Science, 173, pp.364–371. doi:https://doi.org/10.1016/j.procs.2020.06.042.
- Rehman, M. H. ur, Yaqoob, I., Salah, K., Imran, M., Jayaraman, P. P. and Perera, C. (2019). The role of big data analytics in industrial Internet of Things. Future Generation Computer Systems, 99, pp. 247–259.
- Sadhu, P.K., Yanambaka, V.P. and Abdelgawad, A. (2022). Internet of Things: Security and Solutions Survey. Sensors, 22(19), p. 7433.

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References and Further Reading

- Salih, K.O.M., Rashid, T.A., Radovanovic, D. and Bacanin, N. (No date). A Comprehensive Survey on the Internet of Things with the Industrial. Sensors.
- Spektor, H. (2024). IoT Analytics: Types, Challenges, and Best Practices [2024 Guide] | Sternum IoT. [online] Sternum IoT. Available at: https://sternumiot.com/iot-blog/iot-analytics-types-challenges-and-best-practices-2024-guide/.
- Ta-Shma, P., Akbar, A., Gerson-Golan, G., Hadash, G., Carrez, F. and Moessner, K. (2018). An Ingestion and Analytics Architecture for IoT Applied to Smart City Use Cases. IEEE Internet of Things Journal, 5(2), pp.765–774. doi:https://doi.org/10.1109/jiot.2017.2722378.
- Telenor IoT (2016). Scania: Rolling along Smoothly. [online] Telenor IoT. Available at: https://iot.telenor.com/iot-case/scania/.
- ThingSpeak (2024). IoT Analytics - ThingSpeak Internet of Things. [online] Mathworks.com. Available at: https://thingspeak.mathworks.com/.
- Wöbker, C., Seitz, A., Mueller, H. and Bruegge, B. (2018). Fogernetes: Deployment and management of fog computing applications. In Proceedings of the NOMS 2018—2018 IEEE/IFIP Network Operations and Management Symposium, pp. 1–7. Taipei, Taiwan, 23–27 April 2018.
- Xie, X., Wu, D., Liu, S. and Li, R. (2017). IoT Data Analytics Using Deep Learning. [online] arXiv.org. Available at: https://arxiv.org/abs/1708.03854 [Accessed 19 Feb. 2025].
- Yahuza, M. et al. (2020). Systematic review on security and privacy requirements in Edge computing: State of the art and future research opportunities. IEEE Access, 8, pp. 76541–76567.
- Yang, S., Chen, Y. and Yang, Z. (2022). Research on Security and Privacy Problem in the Data Life Cycle for the IoT Scenario. IEEE. doi:https://doi.org/10.1109/ASSP54407.2021.00021.

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Unit Completed - What's Next?

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Your feedback and results will help you track your progress and support continuous improvement of the training experience.

By completing this quiz, you will also become eligible to receive a certificate of successful training completion.

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