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Edge computing

This POSTnote describes edge computing, the use of computing resources in close proximity to the place where data are processed within a network, and some of the opportunities and challenges associated with its use. It supplements POSTnote 629.

Overview

- Edge computing describes the use of computing resources that are in close geographical proximity to the place where data are generated, processed or stored within a network.
- It can enable fast data processing and reduces the need to transfer large amounts of data across the network.
- Edge computing can support the adoption of emerging technologies, including autonomous vehicles and smart manufacturing.
- Coordinating devices on the network, and ensuring data authenticity, privacy and security are some of the challenges facing widespread adoption.

Background

In cloud computing, data are transferred, via telecommunications networks, to be stored or processed by remote computing resources provided by data centres (POSTnote 629). It takes time for data to travel back and forth from the data centre (the delay this causes is known as latency), and transferring a large quantity of data in a timely manner requires high bandwidth, which can be expensive (bandwidth is a measure of the amount of data that can be sent or received in a given period of time).[1,2] This poses challenges for many modern and emerging technologies, such as autonomous vehicles or Internet of Things (IoT) devices, that generate increasingly large amounts of data and may need to make fast decisions based on analysis of that data.[2–4] The emergence of these applications is one factor driving the development of edge computing.[5–7]

Although definitions vary, edge computing usually describes a network with distributed computing resources (including data storage and processing) where some of the physical infrastructure that hosts these resources is located in close geographical proximity to where data are generated or needed for processing.[8] For example, a facial recognition camera might contain a locally installed microcomputer that is able to carry out initial analysis of images on-device in real time.[9] In addition to reducing latency, edge computing can enhance privacy by allowing sensitive data to be stored locally rather than transferred across the network, and can ensure local data processing continues if the connection to the network is lost.[2] However, edge computing resources are generally less powerful than those provided by the cloud. So, for some applications, cloud computing, or a flexible approach that uses both, may be more appropriate.[2] Edge computing is considered to be an emerging technology that has not yet reached maturity,[10] but advances in mobile computing have made it more feasible as portable devices can now support greater, local computing power.[11]

In 2018, the research firm Gartner reported that around 10% of commercially created data were processed outside of a cloud data centre and this was predicted to rise to 75% by 2025.[12] In 2019, market research firm IDC predicted that, in 2020, over half of European organisations will make use of edge computing alongside cloud computing.[2] However, the distributed nature of edge computing, and the need for many individual devices to connect and interact, may pose a number of challenges to its widespread adoption.[13]

This POSTnote discusses the form that an edge computing network might take, and outlines emerging applications and some of the challenges facing widespread adoption.

Edge computing infrastructure

The main components of an edge computing network are usually a cloud computer, edge computers, and a telecommunications network connecting these components to

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each other and to end users.[7] Examples of types of edge computers include: edge data centres that are close enough to users to provide low latency computation, computers in the boots of cars, or microcomputers that are directly integrated into devices.[14–16] Applications that use mobile networks are expected to benefit from the roll out of 5G (POSTbrief 32),[17] which will allow for faster data transfer and the interfacing of multiple mobile devices.[18]

For many applications, edge computers are connected to sensors that provide them with data.[2] Examples of sensors could include cameras, microphones and thermometers. Edge computers are capable of processing and storing sensor data independently from the cloud. However, a remote cloud data centre may be able to carry out more resource-intensive analysis of the data and may be used for long-term data storage or may undertake analysis of data generated by a large number of different sensors.[14,19] For example, a sensor with an integrated edge computer might collect temperature data that could be analysed and used to adjust the temperature of a manufacturing facility. A summary of this data could be sent to the cloud to compare with another facility in a different location.[20]

Energy use
Edge computing can be more energy efficient than transferring large volumes of data to the cloud. This can extend the battery life of edge-enabled mobile devices, and widespread uptake of edge could help to reduce the overall energy consumption of digital infrastructure.[21–24] However, there are concerns that edge computing hardware and applications are more difficult to optimise for efficiency than large cloud data centres, which could result in increased energy demand overall.[6,25,26]

Applications
Examples of possible applications of edge computing include:

- **Transport.** Autonomous vehicles will carry a large number of sensors and generate substantial volumes of data that will be used to make many decisions that could impact passenger safety. Researchers have suggested that the vehicles could be controlled by a combination of in-vehicle computers, edge data centres in the vehicle’s vicinity and remote cloud computing resources. These components would have different roles: in-vehicle computers enable decisions to be made in the event that the network connection is lost, the edge data centre can be used to quickly coordinate communication between vehicles and roadside sensors, and the cloud is able to collect and analyse data from a large number of vehicles.[4,27]
- **Smart manufacturing.** Smart manufacturing broadly describes integrating physical infrastructure with digital, data-driven, technologies, such as artificial intelligence, in order to improve production.[28] Edge computing could help carry out real-time performance monitoring and predictive maintenance on production lines.[29–31]
- **Healthcare.** There are a number of possible applications of edge computing in healthcare.[32] One example, and a subject of current research, is the analysis of data from wearable sensors to detect a possible emergency situation, such as an elderly person’s fall.[33,34] Some healthcare applications may benefit from the additional privacy offered by processing data locally on an edge computer.[32]

Challenges for wider adoption
Edge coordination and management
Coordinating data exchange and sharing computational tasks between a potentially large number of computers or devices in a distributed edge computing network may pose a significant challenge.[8,13] There may be particular difficulties if edge computers are working with a wide range of mobile devices that may not be consistently connected to the network.[35] Researchers are actively trying to improve methods to monitor available computational resources, allocate them efficiently and recombine the results.[14,36] Many stakeholders highlight that interoperability between devices – using standardised ways of communicating and executing tasks – is important for edge computing applications to work effectively.[37]

Authenticity and traceability
Edge computers can process data locally to make real-time decisions. Having central oversight and governance policies in place can help to ensure that local decisions made by edge computers are trustworthy, explainable and can be challenged if necessary.[38–40] Ensuring that the sensor data feeding into edge computers is authentic and interpreted correctly is also important to maintain confidence in edge decisions.[41,8,42]

Security
An edge computing network containing many devices presents many possible entry points for a cyber-attack that could allow attackers to compromise other parts of the network.[43] This could place limits on where critical applications can be run or sensitive data stored.[44] To secure the network, it may be necessary to ensure each individual component is sufficiently secure.[20] For example, authentication systems may be required to ensure that only permitted users can access certain devices or data.[43] Researchers and companies are developing and promoting new technologies to improve security features, such as encryption (POSTbrief 19), on resource constrained devices without affecting performance.[43,45,46]

Edge networks that contain consumer devices may be particularly susceptible to security breaches caused by device vulnerabilities, such as limited cybersecurity features or a lack of regular security updates (POSTnote 593). The UK Government has recently proposed legislation to ensure that manufacturers of internet-connected devices adhere to some common cybersecurity standards to protect consumers.[47]

Privacy
Edge computing may offer some privacy advantages where personal data can be stored locally, and processed or anonymised before being sent for external analysis.[2,14,20,48] This may also allow organisations to better comply with data residency requirements (POSTnote 629).[49] However, as data collecting devices are increasingly adopted by consumers, it may become more difficult to determine different stakeholders’ responsibilities under data protection law and whether they are equipped to comply.[50,51]

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1. SAS *et al.* (2019). Data analytics at the edge. 21.
2. IDC *The Technology Impacts of Edge Computing in Europe*. 10. IDC.
3. Anadiotis, G. Why autonomous vehicles will rely on edge computing and not the cloud. *ZDNet*.
4. Liu, S. *et al.* (2019). Edge Computing for Autonomous Driving: Opportunities and Challenges. *Proceedings of the IEEE*, Vol 107, 1697–1716.
5. Red Hat What is Edge Computing?
6. Daley, S. Putting edge computing centre stage in the UK's fourth industrial revolution. *Computer Weekly*.
7. Carlini, S. *The Drivers and Benefits of Edge Computing*. 8. Schneider.
8. Industrial Internet Consortium (2019). The Edge Computing Advantage.
9. Sync, C. R. M. Guest blog: Edge powering social distancing at St Pancras station.
10. 5 Trends Appear on the Gartner Hype Cycle for Emerging Technologies, 2019.
11. Mayuram, R. Council Post: Living On The Edge (Part II): What's Driving Edge Computing? *Forbes*.
12. van der Meulen, R. What Edge Computing Means for Infrastructure and Operations Leaders. *Gartner*.
13. Shi, W. *et al.* (2016). Edge Computing: Vision and Challenges. *IEEE Internet Things J.*, Vol 3, 637–646.
14. Yousefpour, A. *et al.* (2019). All one needs to know about fog computing and related edge computing paradigms: A complete survey. *Journal of Systems Architecture*, Vol 98, 289–330.
15. Abbas, N. *et al.* (2018). Mobile Edge Computing: A Survey. *IEEE Internet Things J.*, Vol 5, 450–465.
16. Uptime Institute (2017). Data Centres at the Edge.
17. Mobodexter (2019). Key Drivers of the Edge Computing Market. *Medium*.
18. Gezer, V. *et al.* (2017). An Extensible Edge Computing Architecture: Definition, Requirements and Enablers. 6.
19. Gill, B. *et al.* *The Edge Completes the Cloud: A Gartner Trend Insight Report*. 26.
20. Industrial Internet Consortium (2018). Introduction to Edge Computing in IIoT.
21. Yu, W. *et al.* (2018). A Survey on the Edge Computing for the Internet of Things. *IEEE Access*, Vol 6, 6900–6919.
22. LF Edge (2020). Enabling a More Sustainable Energy Model with Edge Computing. *LF Edge*.
23. STL Partners (2017). Edge computing: Changing the balance of energy consumption in networks. *STL Partners*.
24. GSMA (2018). Opportunities and Use Cases for Edge Computing in the IoT.
25. Hittinger, E. *et al.* (2019). Internet of Things: Energy boon or bane? *Science*, Vol 364, 326–328.
26. Hamm, A. *et al.* (2020). Edge Computing: A Comprehensive Survey of Current Initiatives and a Roadmap for a Sustainable Edge Computing Development. 15.
27. Stevens, A. *et al.* (2017). Cooperative automation through the cloud: The CARMA project. in *Proceedings of 12th ITS European Congress*.
28. Ward, M. (2016). Fourth Industrial Revolution. *House of Commons Library Briefing*,
29. Jeschke, S. *et al.* (2017). Industrial Internet of Things. Springer.
30. Chen, B. *et al.* (2018). Smart Factory of Industry 4.0: Key Technologies, Application Case, and Challenges. *IEEE Access*, Vol 6, 6505–6519.
31. Wood, P. (2020). What is the edge opportunity in manufacturing? *techUK*.
32. Edge Computing in Healthcare: Experts Explain How IoT Will Change the Landscape.
33. Ajerla, D. *et al.* (2019). A Real-Time Patient Monitoring Framework for Fall Detection. *Wireless Communications and Mobile Computing*.
34. Chen, Y. *et al.* (2020). An Edge Computing Based Fall Detection System for Elderly Persons. *Procedia Computer Science*, Vol 174, 9–14.
35. Security, complexity and Huawei; protecting the UK's telecoms networks.
36. Hong, C.-H. *et al.* (2019). Resource Management in Fog/Edge Computing: A Survey on Architectures, Infrastructure, and Algorithms. *ACM Comput. Surv.*, Vol 52, 97:1–97:37.
37. Royal Academy of Engineering *et al.* (2018). *Internet of Things realising the potential of a trusted smart world*.
38. Sharma, S. K. *et al.* (2017). Live Data Analytics With Collaborative Edge and Cloud Processing in Wireless IoT Networks. *IEEE Access*, Vol 5, 4621–4635.
39. Petras - – Evaluating Trustworthiness of Edge-Based Multi-Tenanted IoT Devices (TEAM).
40. Liu, D. *et al.* (2019). A Survey on Secure Data Analytics in Edge Computing. *IEEE Internet of Things Journal*, Vol 6, 4946–4967.
41. Guardtime, M. G. (2013). How to Ensure Authenticity in Big Data. *Wired*.
42. APPG on Data Analytics (2019). *Trust, Transparency and Tech*.
43. Copper Horse (2019). Securing IoT Solutions By Design. ARM.
44. NCSC *et al.* (2020). The future of telecoms in the UK.
45. Jan, M. A. *et al.* (2019). SmartEdge: An end-to-end encryption framework for an edge-enabled smart city application. *Journal of Network and Computer Applications*, Vol 137, 1–10.
46. Lightweight devices demand right-sized cryptography. *MIT Technology Review Insights*.
47. Government to strengthen security of internet-connected products. *GOV.UK*.
48. McKinsey & Company (2018). New demand, new markets: What edge computing means for hardware companies.
49. IBM (2020). What Is Edge Computing.
50. Edwards, L. *et al.* (2019). Data subjects as data controllers: a Fashion(able) concept? *Internet Policy Review*.
51. Chen, J. *et al.* (2019). Who Is Responsible for Data Processing in Smart Homes? Reconsidering Joint Controllership and the Household Exemption. *SSRN Journal*,