Research
Based
Curricula

The Internet of Things, Fog Computing and Cloud Computing

Key Stage 5 Computer Science

2019

BROUGHT TO YOU BY RBC ACCESS ED

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For Pupils
Welcome

To get into the best universities, you must demonstrate that you are intellectually curious, and will make the most of the wonderful academic opportunities available to you.

One of the best ways of demonstrating this, is by going above and beyond what is taught in school and studying something that is not on the curriculum.

This resource will give you exactly such an opportunity. You will have something interesting to write about in your application to university, something interesting to talk about in a university interview, and open whole new areas of study you might be interested in!

You will develop valuable academic skills as you go, that we have marked out with gold badges (see the next page on university skills). As you work through the resource you can look out for these badges so that you can explain which skills you have developed and what you did to demonstrate them. Developing these skills will help you get university ready!

If you have any questions while you are using the resources in this pack, you can contact your teacher or email us directly at schools@access-ed.ngo.

Good luck with your journey to higher education!

For Pupils
University Skills

To complete this resource, you will have to demonstrate impressive academic skills. When universities are looking for new students, they will want young people who can study independently and go above and beyond the curriculum. All of these skills that you will see here will demonstrate your abilities as a university student – while you're still at school!

Every time you have to look something up, or write up a reference you are showing that you can work independently. Every time that you complete a challenging problem or write an answer to a difficult question, you might demonstrate your ability to think logically or build an argument. Every time that you evaluate the sources or data that you are presented with, you are showing that you can "dive deep" into an unfamiliar topic and learn from it.

Here are the skills that you will develop in this course:

independent research	your ability to work on your own and find answers online or in other books
creativity	your ability to create something original and express your ideas
problem solving	your ability to apply what you know to new problems
building an argument	your ability to logically express yourself
providing evidence	your ability to refer to sources that back up your opinions/ ideas
academic referencing	your ability to refer to what others have said in your answer, and credit them for their ideas
deep dive	your ability to go above and beyond the school curriculum to new areas of knowledge
source analysis	your ability to evaluate sources (e.g. for bias, origin, purpose)
data interpretation	your ability to discuss the implications of what the numbers show
active reading	your ability to engage with what you are reading by highlighting and annotating

For Teachers
RBC Guide

Programme Aims

The Research-Based Curriculum aims to support student attainment and university progression by providing classroom resources about cutting-edge research at local universities. The resources are designed to:

- ✓ promote intellectual curiosity through exposure to academic research
- ✓ stretch and challenge students to think deeply about content that may be beyond the confines of the curriculum
- ✓ develop core academic skills, including critical thinking, metacognition, and written and verbal communication
- ✓ inform students about how subjects are studied at university, and provide information, advice and guidance on pursuing subjects at undergraduate level

Content

The programme represents a unique collaboration between universities and schools. Trained by AccessEd, PhD Researchers use their subject expertise to create rich resources that help bring new discoveries and debates to students.

The Research-Based Curriculum offers ten modules suitable for either KS4 or KS5 study. The modules span a range of disciplines, including EBacc and A-level subjects, as well as degree subjects like biochemistry. Each module includes six hours of teaching content, supported by student packs, teacher notes and slides. All modules are available online and free of charge for teachers at select schools.

Delivery

Resources are designed to be used flexibly by teachers. The resources can be completed by students individually or in groups, in or out of the classroom.

For Teachers
RBC Guide

Here are five examples of delivery options:

Extra-Curricular Subject Enrichment Clubs

The resources can be completed in small groups (4-8 pupils) across a series of weekly lunch clubs or after-school clubs. Groups can reflect on their learning by presenting a talk or poster on the subject matter at the end of the course.

University Access Workshops

The resources can be used by students to explore subjects that they are interested in studying at university. This can inform their decision making with regards to university degree courses, and allow students to write more effective personal statements by including reflections on the Research-Based Curriculum.

Research Challenge

The resources can be used to ignite curiosity in new topics and encourage independent research. Schools could hold a research challenge across a class or year group to submit a piece of work based on the resources. Pupils could submit individually or in small groups, with a final celebration event.

Summer Project

Resource packs can function as 'transition' projects over the summer, serving as an introduction to the next level of study between KS3 and KS4, or KS4 and KS5. Students could present their reflections on the experience in a journal.

Evidence

The Research-Based Curricula programme builds on the University Learning in Schools programme (ULiS), which was successfully delivered and evaluated through the London Schools Excellence Fund in 2015. The project was designed in a collaboration between Achievement for All and The Brilliant Club, the latter of which is the sister organisation of AccessEd. ULiS resulted in the design and dissemination of 15 schemes of work based on PhD research for teachers and pupils at Key Stage 3. The project was evaluated by LKMCo. Overall, pupils made higher than expected progress and felt more engaged with the subject content. The full evaluation can be found here: ULiS Evaluation.

Questions?

For more information contact hello@access-ed.ngo

Introduction to Topic

Internet of Things, Fog Computing and Cloud Computing

The topics within this pack will include:

Internet of Things

Internet of Things Applications

What is Cloud Computing?

Fog Computing: A bridge for Cloud Computing and Users

Data Aggregation for Fog Computing

Fog Computing and Quality of Service

The Internet of Things (IoT) is influencing our life style from the way we react to the way we behave. From air conditioners that you can control with your smart phone, to smart cars providing the shortest route or your smart watch which is tracking your daily activity. IoT is a giant network of connected devices.

These devices gather and share data about how they are used and the environment in which they are operated. It is all done using sensors, sensors are embeded in every physical device. It can be your mobile phone, electrical appliances, vehicles, bar code sensors, traffic lights and almost everything that you come across in day to day life.

These sensors continuously emit data about the working state of the devices. But the important question is, how do they share this huge amount of data and how do we put this data to our benefit. IoT provides a common platform for all these devices to communicate with each other. Data is emitted from various sensors and sent to IoT platform securely. IoT platform integrates the collected data from various sources. Further analytics is performed on the data and valuable information is extracted as per requirements. Finally, the result is shared with other devices for better user experience, automation and improving efficiency.

Why do we use IoT? The best reason is that we the human beings are lazy, and we want to automate everything, we need to control everything, and we want to see data in real time. This is mainly why we use IoT.

This pack consists 6 lessons on IoT and the related topics of Fog Computing and Cloud Computing. You will integrate your current A level computer science knowledge with IoT, Fog Computing and Cloud Computing.

Introduction to Subject Computer Science at University

Would you like to play a part in the exciting and rapid changes in communication systems that impact on our daily lives? Do cutting-edge technologies such as 3D graphics, virtual reality and artificial intelligence appeal? You'll learn how computer programmes work, how users interact with them and design new systems using programming languages. Software makes modern life possible. Computer Science equips you with vital skills that will put you at the forefront of software development and programming.

Software is everywhere – running everything from our desktop computers and mobile phones to home appliances, game consoles, cars, planes and industrial machinery. This degree will help you become a skilled computer programmer, adept at developing software and fully aware of the tools and methodologies that underpin software. To be a successful, knowledgeable and highly employable computer programmer, you need to know computer science – the subject that underlies computer programming and software development.

IoT, the subject of this pack, is an interdisciplinary subject that has increased its application enormously in recent years in light of its vast scope. IoT generally refers to a growing network of internet-connected devices that find various applications in Engineering and Sciences. If you are studying computer science, then IoT, Fog Computing and Cloud computing could be your future as you are already learning its basics.

Meet the PhD Researcher Mohammad Shahzad

I completed two Bachelors (Electronics and Education), and three Masters (Electrical Engineering, Electronics and Education). During my Masters I worked on Optical Networks. I am currently a Full-Time PhD student in the Department of Computing, University of Derby. A PhD or Doctor of Philosophy is a UK level 8 qualification – the highest level. During a PhD, a researcher produces his own work which is tested and compared to other research. Completing a PhD involves writing a thesis of up to 100,000 words. It also involves publishing your work in journals. My PhD research is on the Internet of Things (IoT) and Fog Computing. I am working towards data aggregation in Fog Computing and Quality of Service (QoS) for IoT applications. During my PhD, I will solve network bottlenecks using data aggregation and QoS for data packets. I am also targeting to improve network throughput, packet loss ratio and bandwidth.

With more than five years of teaching experience in Pakistan from school to university level and two years in Saudi Arabia, I have a great interest in working with students. I have taught Bachelor of Computer Science and Bachelor of Information Technology. Currently I am also a Graduate Teaching Assistant at the same university. I am keen to help students of any age group. Mentoring the students to get through their hard times and showing them a bright side of future is my goal.

Glossary

Term	Definition
Aggregation	joining multiple data packets for transmission as a single unit to increase network efficiency
Bandwidth	amount of data that can be transmitted in a fixed amount of time
Big Data	extremely large data sets that may be analysed computationally to reveal patterns, trends, and associations, especially relating to human behaviour and interactions.
Bottleneck	capacity of an application or a computer system is severely limited by a single component
Cloud computing	the practice of using a network of remote servers hosted on the Internet to store, manage, and process data, rather than a local server or a personal computer.
Congestion	network node or link is carrying more data than it can handle.
Control overhead	combination of excess or indirect computation time, memory, bandwidth, or other resources that are required to perform a specific task.
Data analytics	drawing insights from raw information sources
Edge Computing	a distributed computing paradigm in which computation is largely or completely performed on distributed device nodes
Gateway	routes the traffic from a workstation to the outside network that is serving the Web pages
IoT	Internet of Things
Latency	the delay before a transfer of data begins following an instruction for its transfer.
QoE	Quality of Experience: measure of the overall level of customer satisfaction with a vendor

Glossary

Term	Definition
QoS	Quality of Service: description or measurement of the overall performance of a service
Real time	response within specified time constraints, often referred to as "deadlines"

Resource One Overview

Topic	Internet of Things
A-Level Modules	Big Data
Objectives	After completing this resource students should be able to: ✓ Describe the background and context of the Internet of Things ✓ Explain issues facing the Internet of Things
Instructions	1. Read the data source 2. Complete the activities 3. Explore the further reading

The Internet of Things?

Resource One
Data Source

Computers are now part of everyday life. For most of us, technology is essential to our lives, at home and at work. 'Computational thinking' is a skill children must be taught if they are to be ready for the workplace and able to participate effectively in this digital world.

Kevin Ashton, co-founder of the Auto-ID Centre at MIT, first mentioned the internet of things in a presentation he made to Procter & Gamble (P&G) in 1999. Wanting to bring radio frequency ID (RFID) to the attention of P&G's senior management, Aston called his presentation "Internet of Things" to incorporate the cool new trend of 1999: the internet. MIT professor Neil Gershenfeld's book, When Things Start to Think, also appearing in 1999, did not use the exact term but provided a clear vision of where Internet of Things (IoT) was headed.

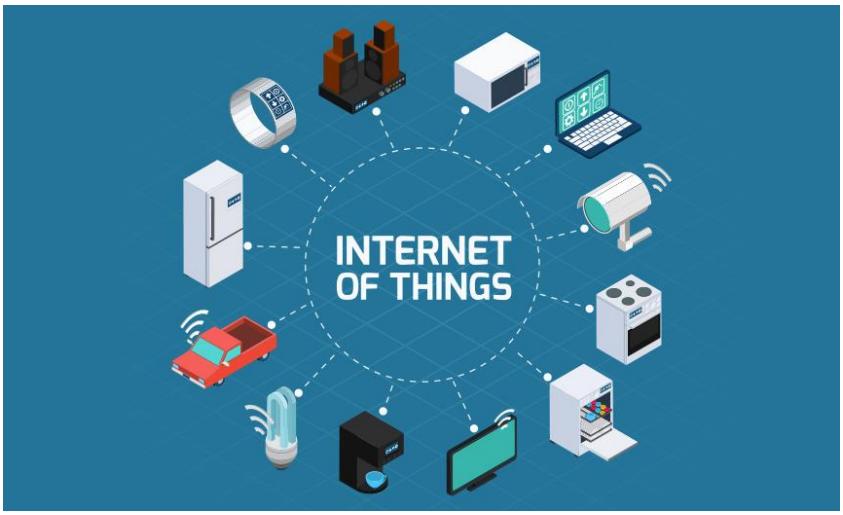
The first internet appliance, for example, was a Coke machine at Carnegie Mellon University in the early 1980s. Using the web, programmers could check the status of the machine and determine whether there would be a cold drink awaiting them, should they decide to make the trip to the machine.

IoT is the network of physical devices, vehicles, home appliances, and other items embedded with electronics, software, sensors, actuators, and connectivity which enables these things to connect, collect and exchange data. IoT involves extending Internet connectivity beyond standard devices, such as desktops, laptops, smartphones and tablets, to any range of traditionally dumb or non-internet-enabled physical devices and everyday objects. Embedded with technology, these devices can communicate and interact over the Internet, and they can be remotely monitored and controlled. The extensive set of applications for IoT devices is often divided into consumer, commercial, industrial and infrastructure spaces.

Resource One
Data Source

Figure 1

Internet of Things



The IoT offers several benefits to organizations enabling them to:

• monitor their overall business processes

• improve the customer experience

• save time and money

• enhance employee productivity

• integrate and adapt business models

• make better business decisions

• generate more revenue

IoT encourages companies to rethink the ways they approach their business, industries and markets and gives them the tools to improve their business strategies. There is no shortage of IoT market estimations. For example:

• Brain & Company expects annual IoT revenue of hardware and software to exceed $450 billion by 2020.

• McKinsey & Company estimates IoT will have an $11.1 trillion impact by 2025.

Resource One
Data Source

• HIS Markit believes the number of connected IoT devices will increase 12% annually to reach 125 billion in 2030.

• Gartner assesses that 20.8 billion connected things will be in use by 2020, with total spend on IoT devices and services to reach $3.7 trillion in 2018.

The IoT connects billions of devices to the internet and involves the use of billions of data points, all of which need to be secured. Due to its expanded attack surface, IoT security and IoT privacy are cited as major concerns. One of the most notorious recent IoT attacks was Mirai, a botnet that infiltrated domain name server provider Dyn and took down many websites for an extended period in one of the biggest distributed denial-of-service (DDoS) attacks ever seen. Attackers gained access to the network by exploiting poorly secured IoT devices.

Resource One Activities

Activities

1. Explain what is meant by a ‘dumb’ object.
2. In the context of IoT, explain the title of Gershenfeld’s book ‘When Things Start to Think’.
3. Describe the first internet appliance.
4. HIS Markit believes the number of connected IoT devices will increase 12% annually to reach 125 billion in 2030. Estimate the number of devices at present in 2019.

5. Suggest an example of an IoT device in each of the consumer, industrial and infrastructure spaces.
6. Explain why IoT Security is a major concern.

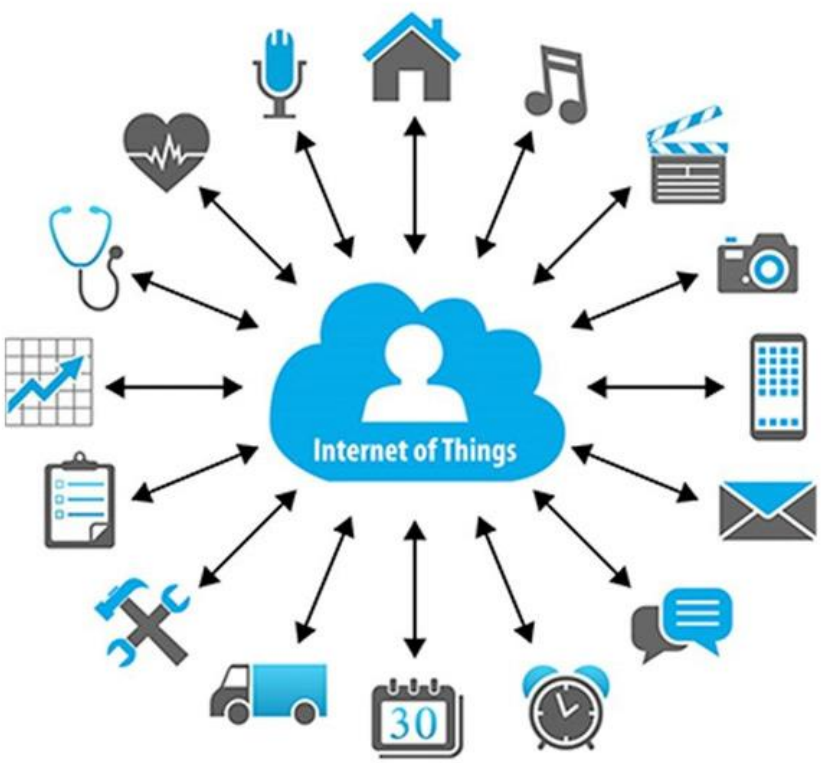
Resource One
Further Reading

Explore

1. Kellmereit, Daniel, and Daniel Obodovski. The silent intelligence: the internet of things. San Francisco, CA: DnD Ventures, 2013.
2. https://www.ibm.com/blogs/internet-of-things/what-is-the-iot/
3. https://www.youtube.com/watch?v=UrwbeOllc68

Resource Two Overview

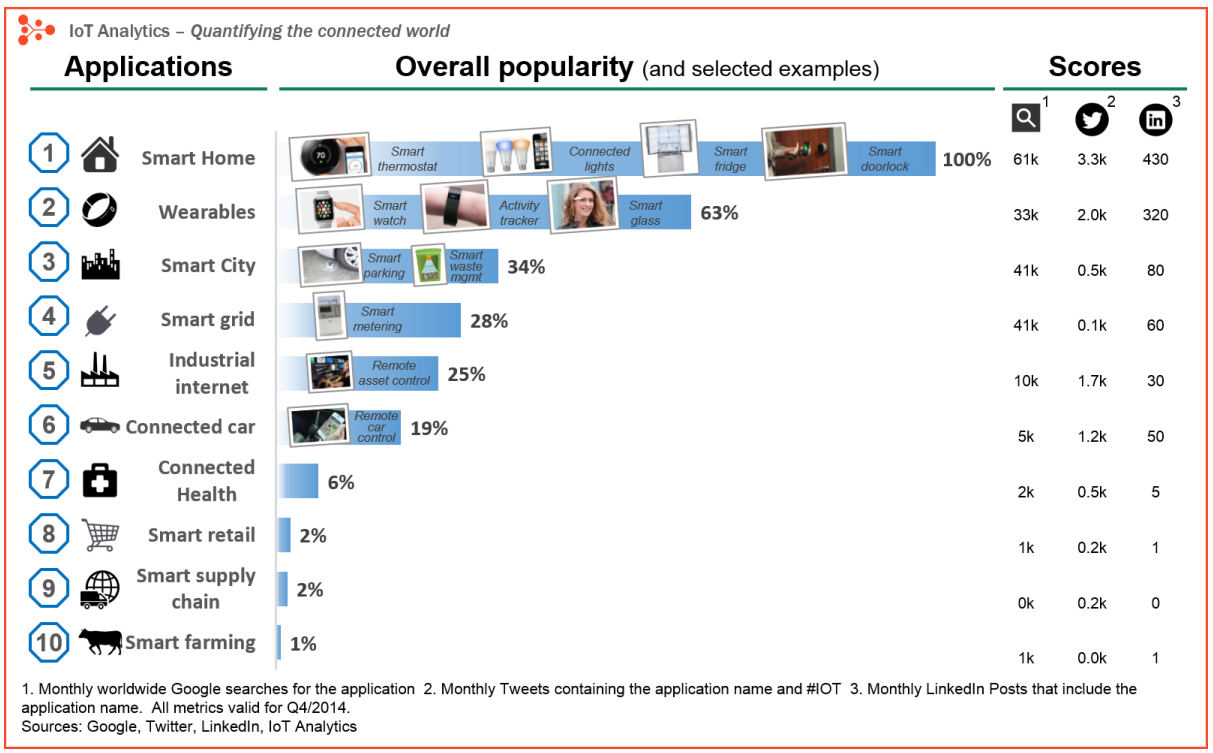
Topic	Internet of Things Applications
A-Level Modules	Input and output devices, wireless networking
Objectives	After completing this resource students should be able to: ✓ Give examples of Internet of Things applications ✓ Describe the impact of IoT on society and individuals.
Instructions	1. Read the data source 2. Complete the activities 3. Explore the further reading



Resource Two
Data Source

Examples of objects that can fall into the scope of Internet of Things include connected security systems, thermostats, cars, electronic appliances, lights in household and commercial environments, alarm clocks, speaker systems, vending machines and more.

The graphic below considers three measures of IoT usage: what people search for on Google, what people talk about on Twitter, and what people write about on LinkedIn. The highest score received a rating of 100%, the other Internet of Things applications were ranked with a percentage that represents the relation to the highest score (relative ranking).



Resource Two
Data Source

1 - Smart home

Smart Home clearly stands out, ranking as highest IoT application on all measured channels. To give an existing example, the Hive app allows customers to control a range of internet-connected devices, from a thermostat, to lights, smart plugs, motion sensors, and window and door sensors. More than 60,000 people currently search for the term "Smart Home" each month. This is not a surprise. The IoT Analytics company database for Smart Home includes 256 companies and start-ups. More companies are active in smart home than any other application in the field of IoT. The total amount of funding for Smart Home start-ups currently exceeds $2.5bn.

2 - Wearables

Wearables remains a hot topic too. There are plenty of other wearable innovations to be excited about: like the Sony Smart B Trainer, the Myo gesture control, or LookSee bracelet. Of all the IoT start-ups, wearables maker Jawbone is probably the one with the biggest funding to date. It stands at more than half a billion dollars!

3 - Smart City

Smart city spans a wide variety of cases, from traffic management to water distribution, to waste management, urban security and environmental monitoring. Its popularity is fuelled by the fact that many Smart City solutions promise to alleviate real pains of people living in cities these days. IoT solutions in Smart City solve traffic congestion problems, reduce noise and pollution and help make cities safer.

Resource Two
Data Source

4 - Smart grids

Smart energy grids are a special one. A future smart grid promises to use information about the behaviours of electricity suppliers and consumers in an automated fashion to improve the efficiency, reliability, and economics of electricity. 41,000 monthly Google searches highlights the concept's popularity. However, the lack of tweets (Just 100 per month) shows that people don't have much to say about it.

5 - Industrial internet

The industrial internet is also one of the special IoT applications. This concerns linking big data to industrial equipment. While many market researches such as Gartner or Cisco see the industrial internet as the IoT concept with the highest overall potential, its popularity currently doesn't reach the masses like smart home or wearables do. The industrial internet however has a lot going for it. The industrial internet gets the biggest push of people on Twitter (~1,700 tweets per month) compared to other non-consumer-oriented IoT concepts.

6 - Connected car

The connected car is coming up slowly. Because the development cycles in the automotive industry typically take 2-4 years, we haven't seen much buzz around the connected car yet. But it seems we are getting there. Most large auto makers as well as some brave start-ups are working on connected car solutions. And if the BMWs and Fords of this world don't present the next generation internet connected car soon, other well-known giants will: Google, Microsoft, and Apple have all announced connected car platforms.

Resource Two
Data Source

7 - Connected Health (Digital health/Telehealth/Telemedicine)

Connected health remains the sleeping giant of the IoT applications. The concept of a connected health care system and smart medical devices bears enormous potential, not just for companies also for the well-being of people in general. For example, a health bracelet might be able to monitor heart rate and other health signs, warning patients and clinicians of problems. Yet, Connected Health has not reached the masses yet. Prominent use cases and large-scale start-up successes are still to be seen.

8 - Smart retail

Proximity-based advertising as a subset of smart retail is starting to take off. But the popularity ranking shows that it is still a niche segment. One LinkedIn post per month is nothing compared to 430 for smart home.

9 - Smart supply chain

Supply chains have been getting smarter for some years already. Solutions for tracking goods while they are on the road or getting suppliers to exchange inventory information have been on the market for years. So, while it is perfectly logic that the topic will get a new push with the Internet of Things, it seems that so far, its popularity remains limited.

10 - Smart farming

Smart farming is an often-overlooked business-case for the internet of Things because it does not really fit into the well-known categories such as health, mobility, or industrial.

Resource Two
Data Source

However, due to the remoteness of farming operations and the large number of livestock that could be monitored the Internet of Things could revolutionize the way farmers work. But this idea has not yet reached large-scale attention. Nevertheless, one of the Internet of Things applications that should not be underestimated. Smart farming will become the important application field in the predominantly agricultural-product exporting countries.

Let us look at a scenario where IoT is doing wonders. Consider a manufacturing company that makes air conditioning units. A machine that assembles the units has sensors attached. The machine continuously sends data regarding machine state to the manufacturer e.g. pressure in the hydraulic system of the machine. This data can be used to diagnose any problems with the machine.

Imagine the machine assembles units and passes them on to a conveyor belt. A bar code is attached to each unit before leaving the belt and scanned. This provides the manufacturer with information. For example, they can track their inventory and ensure they don't run out of stock.

Next, these units are parked and parcelled to different retailers. Each retailer has a bar code reader to track the units coming from different manufacturers.

An air conditioning unit is purchased by a customer. The unit has an embedded sensor that emits data regarding its health and temperature. This data is sent to an IoT platform and analysed continuously, allowing the customer care team to contact the customer for the repair work when necessary.

In the example above, IoT improves automation, efficiency and user experience. This is just one of a million scenarios. The future of IoT is huge.

Resource Two Activities

Activities

1. Describe how it is possible to monitor the popularity of IoT technology.

2. Explain the advantages of having an internet-enabled thermometer in a smart home.

3. Suggest why IoT wearables might be banned in some schools.

4. Invent an IoT device for each of these sectors:

a. Smart healthcare

b. Smart car

c. Smart farm

5. Do you agree with the statement that “automation causes unemployment”?

Resource Two
Further Reading

Explore

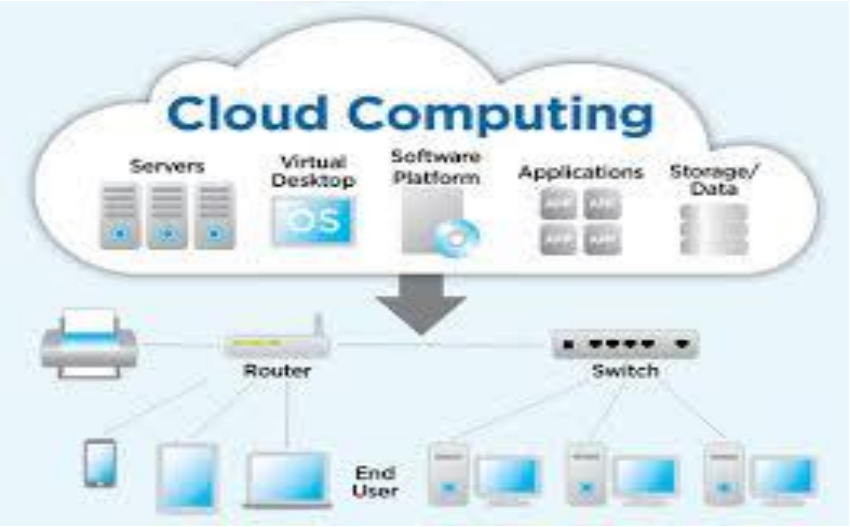
1. https://www.youtube.com/watch?v=91aXs9E0qAI
2. Mihovska, Albena, and Mahasweta Sarkar. "Smart connectivity for internet of things (iot) applications." New Advances in the Internet of Things. Springer, Cham, 2018. 105-118.

Resource Three Overview

Topic	What is Cloud Computing?
A-Level Modules	Big Data
Objectives	After completing this resource student should be able to: ✓ Compare different types of Cloud Computing. ✓ Explain the advantages of Cloud Computing.
Instructions	1. Read the data source 2. Complete the activities 3. Explore the further reading

Resource Three
Data Source

The IoT consists of everyday objects – physical devices, vehicles, buildings etc. with embedded electronics, software, sensors, and network connectivity, allowing them to collect, send and receive data. The IoT generates a vast amount of Big Data and this in turn puts a huge strain on Internet Infrastructure. As a result, this forces companies to find solutions to minimise the pressure and solve their problem of transferring large amounts of data.



Cloud computing is represented schematically in the graphic above. Cloud computing in simple terms means accessing data and programs from a centralised pool of computer resources that can be ordered and consumed on demand. Typically cloud deployments are described in 3 different models; Public, Private or Hybrid.

Deep Dive

• **Private Cloud** Service is a secure cloud that only the specified organisation can access. The additional security offered by a private cloud model is ideal for any organisation, including enterprise, that needs to store and process private data or carry out sensitive tasks. For example, a private cloud service could be utilised by a

Resource Three
Data Source

financial company that is required by regulation to store sensitive data internally and who will still want to benefit from some of the advantages of cloud computing within their business infrastructure, such as on demand resource allocation.

• **Public Cloud** Service is like a Private cloud although the main differentiator is that resources used to process, and store data can be shared with other organisations, and data transferred over a public network such as the internet. Third party providers will deliver cloud services over the internet and are normally charged by CPU cycles, storage, or bandwidth that they require.

• **Hybrid Cloud** is a cloud computing environment which uses a mix of on premise, private cloud and third party public cloud services. With the hybrid cloud model, IT decision makers have more control over both the private and public components than using a pre-packaged public cloud platform.

Cloud computing and the IoT both serve to increase efficiency in everyday tasks and both have a complementary relationship. The IoT generates massive amounts of data, and cloud computing provides a pathway for this data to travel.

Another benefit of Cloud Computing for the IoT is that Cloud Computing enables better collaboration which is essential for developers today. By allowing developers to store and access data remotely, developers can access data immediately and work on projects without delay.

Cloud computing is vital in our daily lives. Following are some real-world examples of cloud computing.

• Examples of cloud storage

(Dropbox, Gmail, Facebook)

Resource Three
Data Source

• Marketing Cloud Platforms

(Hubspot, Adobe Marketing Cloud)

• Cloud Computing in education

(SlideRocket, Ratatype, Amazon Web Services)

• Examples of Cloud Computing in Healthcare

(ClearDATA, IBM Cloud, Dell's secure healthcare cloud)

• Examples of Cloud Computing for Government

(The US Federal Cloud Computing Strategy)

Other examples of Cloud Storage are Google Docs, Xdrive, MediaMax and Strongspace. Perhaps most private computer users are familiar with backup services in the Cloud. Mozy.com and carbonite.com are good examples of this technology.

Finally, by storing data in the Cloud, this enables IoT companies to change directly quickly and allocate resources in different areas. Big Data has emerged in the past couple of years and with such emergence the cloud has become the architecture of choice. Most companies find it feasible to access the massive quantities of Big Data via the cloud.

Resource Three Activities

Activities

1. What is a public cloud?

- ❑ A cloud service that can only be accessed from a publicly shared computer
- ❑ A multi-tenant cloud environment accessed over the internet
- ❑ A cloud environment owned, operated and controlled by a public company

2. Which of the following statements could be used to describe a private cloud deployment?

- ❑ A cloud environment maintained within an enterprise's own data centre
- ❑ A private environment within a third-party or public cloud provider's architecture
- ❑ Both #1 and #2

3. Describe an example of how you have used cloud computing.

4. Advantages of cloud computing include minimized costs, easy access, data backup, data centralization, sharing capabilities, security, free storage. Which do you most value? Explain your answer.

5. Identify risks of Cloud Computing and use clear examples (e.g. evidence) to explain these risks.

Resource Three
Further Reading

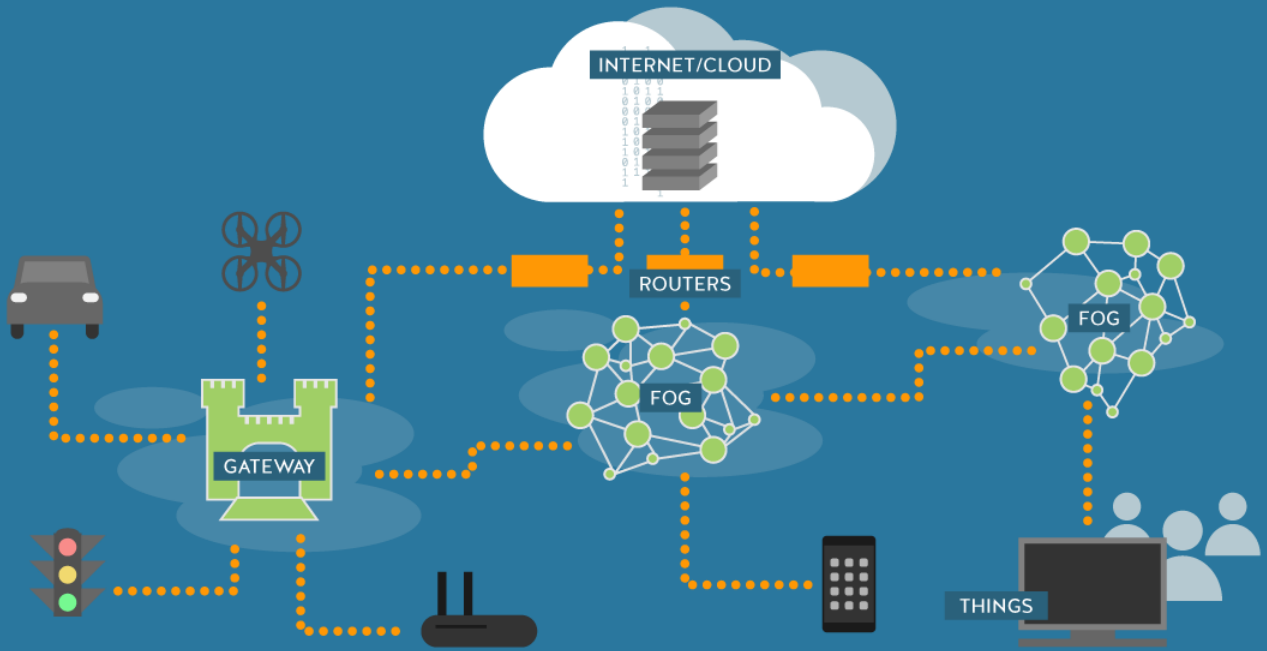
Explore

More on cloud computing:

https://www.youtube.com/watch?v=uYGQcmZUTaw

Resource Four Overview

Topic	Fog Computing: A bridge for Cloud Computing and Users
A-Level Modules	Fundamentals of communication and networking
Objectives	For A Level Computer Science student should be able to: ✓ Explain the purpose of Fog Computing ✓ Discuss issues facing Fog Computing
Instructions	1. Read the data source 2. Complete the activities 3. Explore the further reading



Resource Four
Data Source

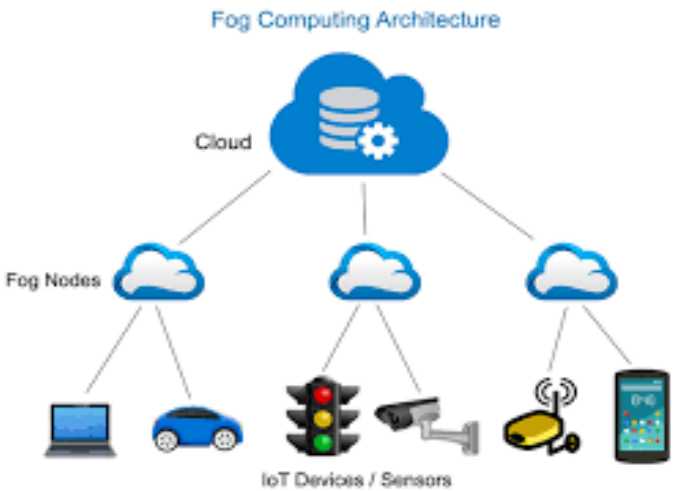
Active Reading

What is Fog Computing?

The Internet of Things (IoT) generates unprecedented amounts of data. Cloud computing can have difficulties in handling Big Data: bottlenecks arise and user experience is compromised. A solution, proposed by Intel and Cisco, is Edge or Fog Computing. Intel calls it Edge Computing and Cisco calls it Fog Computing. Rather than sending all the data to the cloud, data is mainly sent to fog nodes (see Figure 1). By deploying services at the edge of the network, or even end devices such as set-top-boxes or access points, fog computing creates superior end user-experiences.

Figure 1

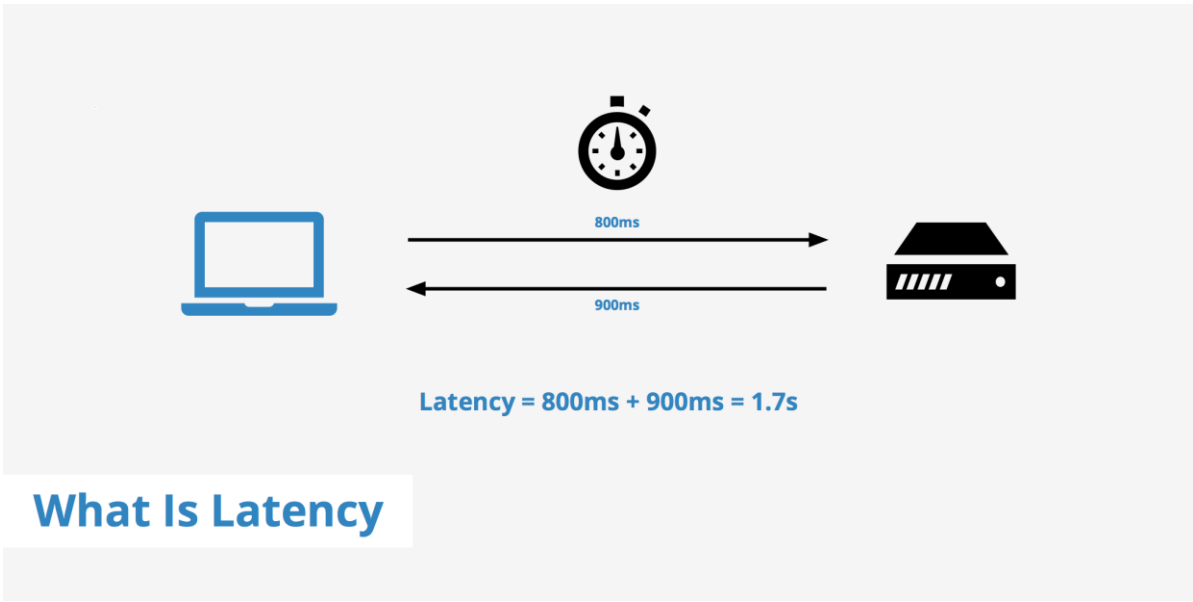
Fog Architecture



When is Fog Computing used?

Fog Computing is used when 'latency' is an issue. Latency is a measure of delay. In a network, latency measures the time it takes for some data to get to its destination across the network. It is usually measured as a round trip delay – the time taken for information to get to its destination and back again (see graphic below).

Resource Four
Data Source



The round-trip delay is an important measure because a computer that uses a TCP/IP network sends a limited amount of data to its destination and then waits for an acknowledgement to come back before sending any more. Thus, the round-trip delay has a key impact on the performance of the network. Latency is usually measured in milliseconds (ms).

There are many applications in which a delay of milliseconds can cause problems. Video streaming is one example. Emergency scenarios in healthcare is another. To avoid these issues with latency, Fog Computing can be used.

Fog Computing is also used when connectivity is irregular or when there are terabytes of data that are not practical to stream to the cloud and back. Connectivity with the cloud can be irregular in geographically dispersed areas where there are network connectivity issues, but service disruption at the edge is rare.

Resource Four
Data Source

Issues facing Fog Computing

Fog computing can integrate edge devices and cloud resources to avoid bottlenecks at the edge. Fog Computing reduces latency and increases bandwidth (the amount of information that can be transferred in a fixed time). Due to its computational power and expanded storage capabilities, Fog Computing is well-positioned for real-time big data and analytics.

However, the number of edge devices is growing at an enormous rate. Consequently, the volume of data will also increase. When a node is overloaded, it affects the service provided to the edge devices that are connected to the node. Strategies will be required to maintain Quality of Service (QoS) and Quality of Experience (QoE). Computational resources will need to expand, or existing resources will need to be used more efficiently.

To avoid overloading nodes, incoming traffic will need to be managed better. A thorough knowledge of the peak hours of usage of edge nodes is required so that tasks can be partitioned and scheduled in a flexible manner. Also, edge nodes cannot handle heavy software, so there is need for alternative light weight algorithms.

Fog Computing is a solution to the data problems facing IoT and its applications. There are millions of applications of IoT and solving their bottlenecks is key. Fog Computing bridges cloud computing with users.

Resource Four Activities

Activities

1. Describe what is meant by the term ‘Big Data’.
2. Explain what is meant by the term ‘Fog Computing’.
3. Define the term ‘latency’.
4. Explain how Fog Computing solves latency problems.
5. Describe an issue facing Fog Computing and a potential solution.

Resource Four
Further Reading

Explore

More on fog computing:

https://www.youtube.com/watch?v=pdmyYbdLnkI

Resource Five Overview

Topic	Data Aggregation for Fog Computing
A-Level Modules	Data aggregation

Objectives

After completing this resource students should be able to:

- ✓ Describe layers of computing in the IoT
- ✓ Explain the purpose of fog bursts
- ✓ Compare fog burst strategies

Instructions

1. Read the data source
2. Complete the activities
3. Explore the further reading

Resource Five
Data Source

Deep Dive

Handling IoT big data

The Internet of Things will be of great benefit to our daily lives. Fog devices deployed at the network edge provide low latency and improve Quality of Service in IoT applications. However, to fully take advantage of IoT, we must address some challenges lying ahead. Many IoT applications generate huge volumes of data for real-time analytics, and as a result, IoT is a big data problem. To manage and analyse the huge volumes of data generated, and to derive value from IoT, we need to consider suitable strategies.

Figure 1 shows the different layers for Fog computing and Cloud Computing. Data gathering or 'data aggregation' will take place at the Network Layer. The data coming from 3G, 4G, 5G, LTE and WiFi will be assembled in the aggregation network through nodes and switches. This aggregated data then will be forwarded to core network and then to the Cloud Layer for further analytics.

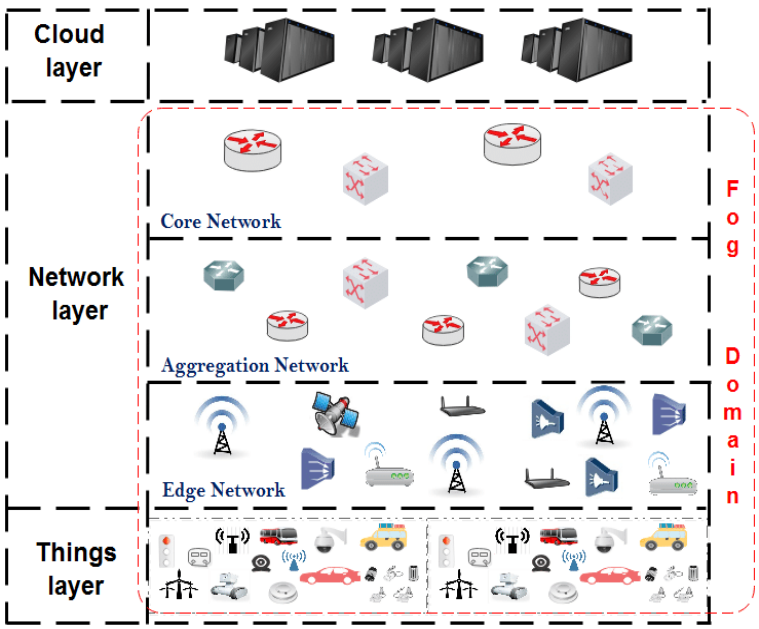


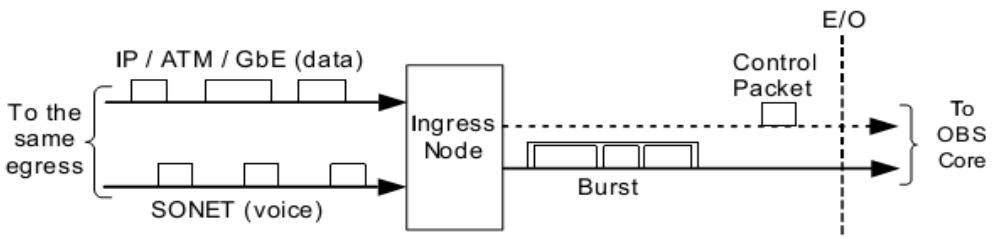
Figure 1

layers in fog and cloud computing. IoT devices in the things layer pass data to devices like wireless routers the in the edge network. Data from these devices are then gathered by nodes and switches in the aggregation network before being forwarded to the core network and cloud layer.

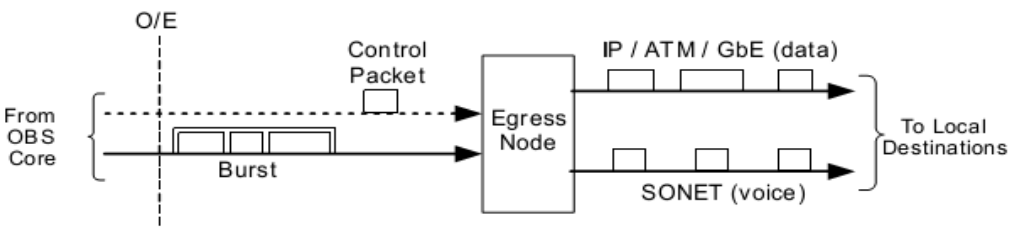
Resource Five
Data Source

Fog Bursts

To improve network throughput we need to aggregate data at a greater rate and avoiding losing data. One solution is to gather data in the form of a Fog Burst (a series of data packets). At the user end, data is assembled into a single burst (Figure 2a). The data are assembled based on having the same destination address, and led by a control packet. The control packet contains control information for delivering the burst, for example: source and destination network addresses, error detection codes, and sequencing information. When delivered at the cloud end, data is disassembled and sent on for processing (Figure 2b).



(a) Burst Assembly



(b) Burst Disassembly

Resource Five Activities

Activities

1. Describe the layers of Fog and Cloud Computing.
2. Define a Fog Burst in a sentence.
3. Explain why a control packet is required for each burst.
4. Explain how bursts reduce overhead.
5. Add a sentence to each box in the grid below.

	Timer-based burst	Length-based burst
If burst is too short...		
If burst is too long...		

6. Explain the hybrid-approach to fog bursts.

Resource Five
Further Reading

Explore

Data packets

https://en.wikipedia.org/wiki/Network_packet

Resource Six Overview

Topic	Fog Computing and Quality of Service
A-Level Modules	Fundamentals of communication and networking
Objectives	After completing this resource students should be able to: ✓ Explain the key benefits of Fog Computing ✓ Explain the key challenges facing Fog Computing
Instructions	1. Read the data source 2. Complete the activities 3. Explore the further reading

Resource Six
Data Source

Here are three reasons why fog computing will play a key part in the rise of the Internet of Things:

1. Fog Computing is the next evolution of cloud computing

Companies often look to the IoT to bridge the gap between information technology and operational technology. Many data-rich resources live in the cloud but are not directly accessible between these two vital departments. Fog computing pushes the intelligence, processing power and communication capabilities of a gateway or appliance directly into devices. These devices can then use fog computing capabilities to determine what data should be stored locally and what data should be sent to the cloud for further analysis. As the IoT grows in capability and connectivity, there will be a move away from cloud computing and a move towards fog computing. Increasingly, edge devices will begin to handle their own processing and storage. These devices will send only the most important data to the cloud and the cloud will analyse and then share what it learned with all the devices.

2. Fog computing alleviates network bandwidth limitations and cuts costs

Transmitting large data sets over a wide network area has a high financial cost. The common solution is to store the same data twice – locally and at the enterprise data centre. But this often requires expensive bandwidth, resulting in service degradation, data latency and security concerns – all which still require additional cost.

Fog computing eliminates the need for costly bandwidth additions. Low-cost edge gateways can keep computing and data storage on the edge. This means much less data needs to be transmitted back to the core server – where enterprise-level applications reside, saving on bandwidth requirements.

3. Fog computing addresses security concerns

Sensors and things on the edge can be especially vulnerable to security threats. Because industrial equipment is typically designed to last for decades, most connected devices today — and for the foreseeable future — will be from legacy equipment already operating in the plant or field. Many of these protocols for industrial communications are not secure by today's standards; some were specifically stripped down and designed for low bandwidth networks back in a time of simpler security threats.

Gateways designed to work with the edge can alleviate security concerns by keeping sensitive data within a local network and analysing it within a secure system. Fog computing also accelerates awareness and response to possible security threats by eliminating a round-trip to the cloud for analysis.

Quality of Service

Figure 1 on the next page outlines the key challenges for Fog Computing. Together the issues feed into the Quality of Service available. QoS can be divided into three aspects: reliability, capacity and delay.

- Reliability. Normally, reliability can be improved through periodic check-pointing to resume after failure, rescheduling failed tasks or replicating to exploit executing in parallel.
- Capacity. To achieve high bandwidth and efficient storage utilization, it is important to investigate how data are placed in the fog network since data locality for computation is very important. The computation cannot start before the data aggregation is finished, which adds delay to services. To solve this, we may leverage user mobility patterns and service request patterns to place data on suitable fog nodes to either minimize the cost of operation, the latency or to maximize the throughput.
- Delay. Latency-sensitive applications, such as streaming or complex event processing, are typical applications which need fog computing to provide real-time streaming processing rather than batch processing. Delay can be caused by contention (see figure 2).

Resource Six
Data Source

Figure 1

Challenges of Fog Computing

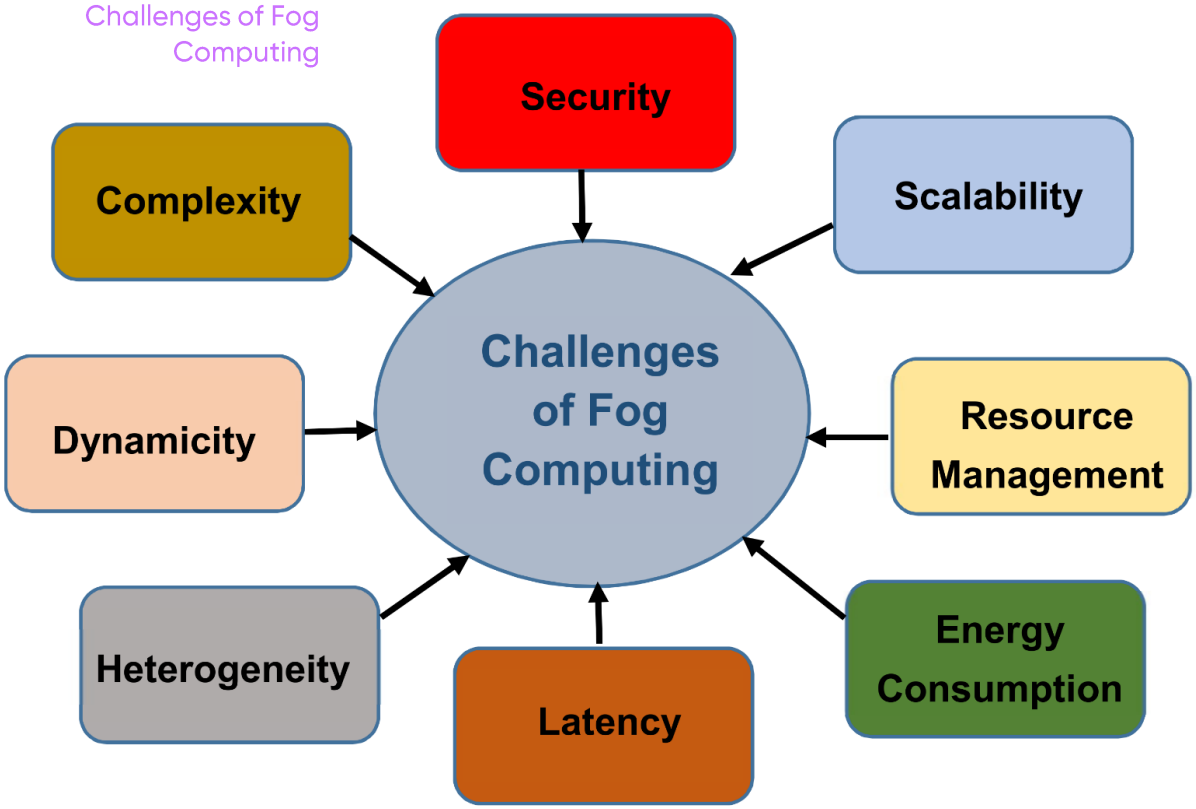
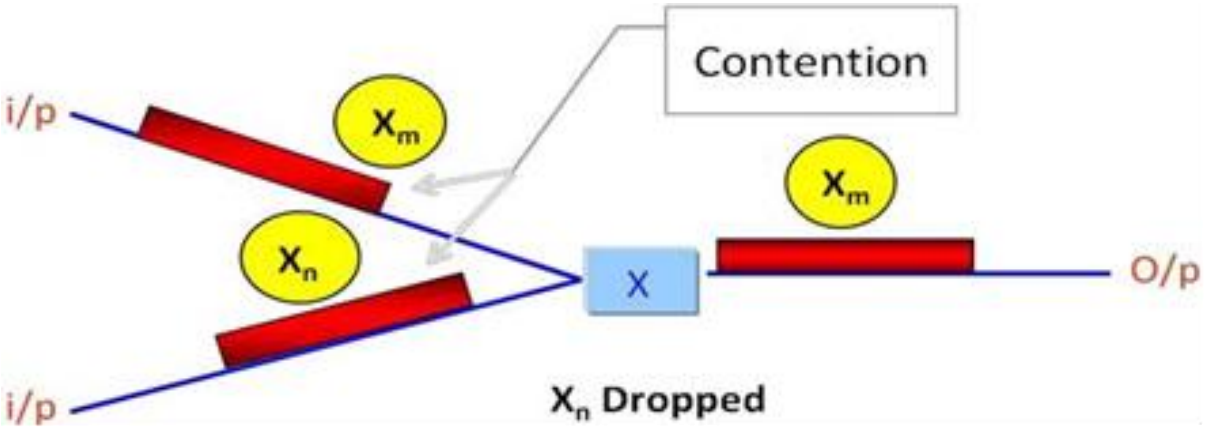


Figure 2

Contention



Contention is the major cause of delay. If two packets tend to reserve the same resources at the same time, contention happens. Here, two packets Xm and Xn tend to reserve switch X but only Xm manages to reserve the link. Xn is dropped because of contention.

Resource Six Activities

Activities

1. "Eventually, all data will be handled via Fog Computing and no data will be handled via Cloud Computing". Do you agree with this statement? Explain your answer.
2. Explain how Fog Computing reduces costs
3. Explain how Fog Computing addresses security concerns.
4. Explain how contention causes latency issues.

Resource Six
Further Reading

Explore

Resource contention:

https://en.wikipedia.org/wiki/Resource_contention

Final Reflection

Deep Dive

BROUGHT TO YOU BY RBC ACCESS ED

Topic

The Internet of Things and Fog Computing

Instructions

Create a Powerpoint Presentation about the Internet of Things and Fog Computing. The key questions to answer in your presentation are:

1) What is the Internet of Things?
2) What are some applications of the Internet of Things?
3) What is cloud computing?
4) What is fog computing?
5) What is the future of the IoT?

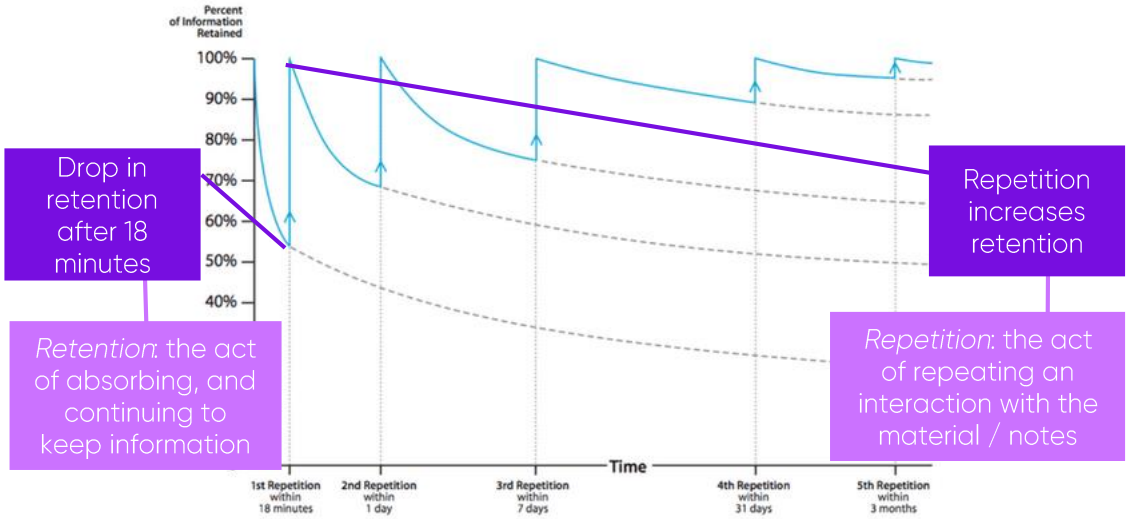
You should use the resources in this pack, along with independent research, to help you prepare the presentation.

University Study Skills
Cornell Notes

Why is good note taking important?

If it feels like you forget new information almost as quickly as you hear it, even if you write it down, that's because we tend to lose almost 40% of new information within the first 24 hours of first reading or hearing it.

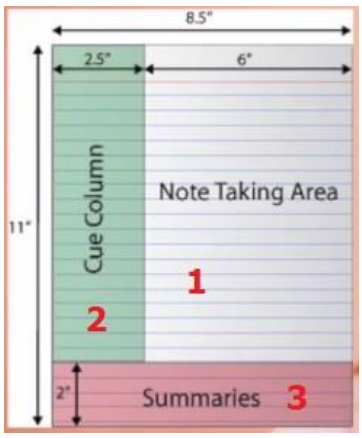
If we take notes effectively, however, we can retain and retrieve almost 100% of the information we receive. Consider this graph on the rate of forgetting with study/repetition:



Learning a new system

The Cornell Note System was developed in the 1950s at the University of Cornell in the USA. The system includes interacting with your notes and is suitable for all subjects. There are three steps to the Cornell Note System.

Step 1: Note-Taking



1. <u>Create Format</u>: Notes are set up in the Cornell Way. This means creating 3 boxes like the ones on the left. You should put your name, date, and topic at the top of the page.

2. <u>Write and Organise</u>: You then take your notes in area on the right side of the page. You should organise these notes by keeping a line or a space between 'chunks' /main ideas of information. You can also use bullet points for lists of information to help organise your notes.

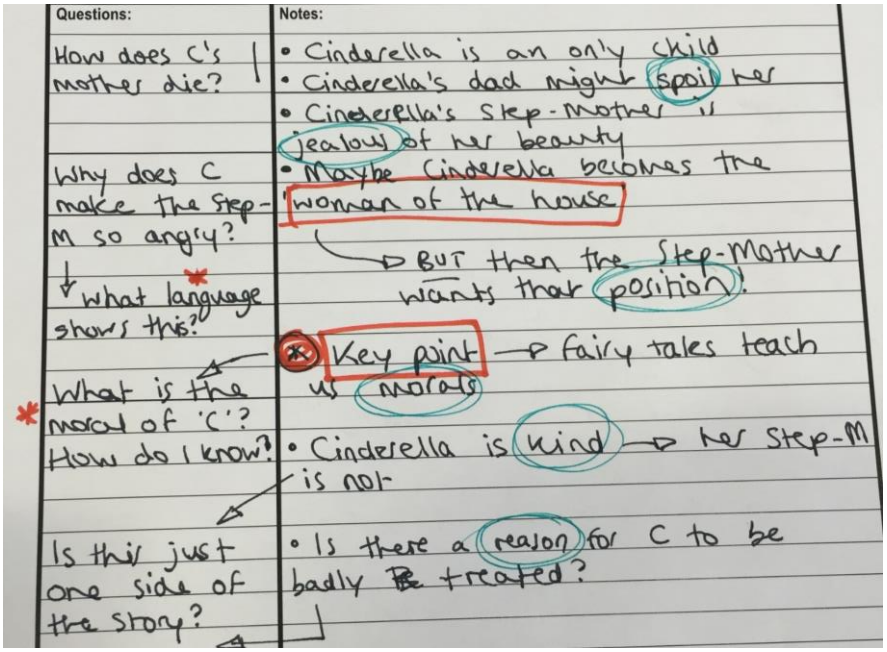
Step 2 Note-Making

1. Revise and Edit Notes: Go back to box 1, the note taking area and spend some time revising and editing. You can do this by: highlighting 'chunks' of information with a number or a colour; circling all key words in a different colour; highlighting main ideas; adding new information in another colour

2. Note Key Idea: Go to box 2 on the left hand side of the page and develop some questions about the main ideas in your notes. The questions should be 'high level'. This means they should encourage you to think deeper about the ideas. Example 'high level' questions would be:

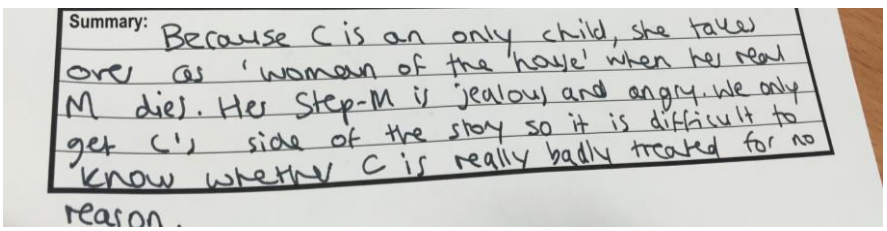
- Which is most important / significant reason for...
- To what extent...
- How does the (data / text / ideas) support the viewpoint?
- How do we know that...

Here is an example of step 1 and step 2 for notes on the story of Cinderella:



Step 3 Note-Interacting

1. Summary: Go to box 3 at the bottom of the page and summarise the main ideas in box 1 and answer the essential questions in box 2.



Give the Cornell Note Taking System a try and see if it works for you!

University Study Skills
Key Instruction Words

These words will often be used when university tutors set you essay questions - it is a good idea to carefully read instruction words before attempting to answer the question.

Analyse – When you analyse something you consider it carefully and in detail in order to understand and explain it. To analyse, identify the main parts or ideas of a subject and examine or interpret the connections between them.

Comment on – When you comment on a subject or the ideas in a subject, you say something that gives your opinion about it or an explanation for it.

Compare – To compare things means to point out the differences or similarities between them. A comparison essay would involve examining qualities/characteristics of a subject and emphasising the similarities and differences.

Contrast – When you contrast two subjects you show how they differ when compared with each other. A contrast essay should emphasise striking differences between two elements.

Compare and contrast – To write a compare and contrast essay you would examine the similarities and differences of two subjects.

Criticise – When you criticise you make judgments about a subject after thinking about it carefully and deeply. Express your judgement with respect to the correctness or merit of the factors under consideration. Give the results of your own analysis and discuss the limitations and contributions of the factors in question. Support your judgement with evidence.

Define – When you define something you show, describe, or state clearly what it is and what it is like, you can also say what its limits are. Do not include details but do include what distinguishes it from the other related things, sometimes by giving examples.

Describe – To describe in an essay requires you to give a detailed account of characteristics, properties or qualities of a subject.

Discuss – To discuss in an essay consider your subject from different points of view. Examine, analyse and present considerations for and against the problem or statement.

University Study Skills
Key Instruction Words

Evaluate – When you evaluate in an essay, decide on your subject's significance, value, or quality after carefully studying its good and bad features. Use authoritative (e.g. from established authors or theorists in the field) and, to some extent, personal appraisal of both contributions and limitations of the subject. Similar to **assess**.

Illustrate – If asked to illustrate in an essay, explain the points that you are making clearly by using examples, diagrams, statistics etc.

Interpret – In an essay that requires you to interpret, you should translate, solve, give examples, or comment upon the subject and evaluate it in terms of your judgement or reaction. Basically, give an explanation of what your subject means. Similar to **explain**.

Justify – When asked to justify a statement in an essay you should provide the reasons and grounds for the conclusions you draw from the statement. Present your evidence in a form that will convince your reader.

Outline – Outlining requires that you explain ideas, plans, or theories in a general way, without giving all the details. Organise and systematically describe the main points or general principles. Use essential supplementary material, but omit minor details.

Prove – When proving a statement, experiment or theory in an essay, you must confirm or verify it. You are expected to evaluate the material and present experimental evidence and/or logical argument.

Relate – To relate two things, you should state or claim the connection or link between them. Show the relationship by emphasising these connections and associations.

Review – When you review, critically examine, analyse and comment on the major points of a subject in an organised manner

University Guidance

Exploring Careers and Study Options

- ✓ Find job descriptions, salaries and hours, routes into different careers, and more at https://www.startprofile.com/
- ✓ Research career and study choices, and see videos of those who have pursued various routes at http://www.careerpilot.org.uk/
- ✓ See videos about what it's like to work in different jobs and for different organisations at https://www.careersbox.co.uk/
- ✓ Find out what different degrees could lead to, how to choose the right course for you, and how to apply for courses and student finance at https://www.prospects.ac.uk/
- ✓ Explore job descriptions and career options, and contact careers advisers at https://nationalcareersservice.direct.gov.uk/
- ✓ Discover which subjects and qualifications (not just A levels) lead to different degrees, and what careers these degrees can lead to, at http://www.russellgroup.ac.uk/media/5457/informed-choices-2016.pdf

Comparing Universities

- ✓ https://www.whatuni.com/
- ✓ http://unistats.direct.gov.uk/
- ✓ https://www.thecompleteuniversityguide.co.uk/
- ✓ Which? Explorer tool – find out your degree options based on your A level and BTEC subjects: https://university.which.co.uk/

UCAS

- ✓ Key dates and deadlines: https://university.which.co.uk/advice/ucas-application/ucas-deadlines-key-application-dates
- ✓ Untangle UCAS terminology at https://www.ucas.com/corporate/about-us/who-we-are/ucas-terms-explained
- ✓ Get advice on writing a UCAS personal statement at https://www.ucas.com/ucas/undergraduate/getting-started/when-apply/how-write-ucas-undergraduate-personal-statement
- ✓ You can also find a template to help you structure a UCAS statement, at https://www.ucas.com/sites/default/files/ucas-personal-statement-worksheet.pdf
- ✓ How to survive Clearing: https://university.which.co.uk/advice/clearing-results-day/the-survivors-guide-to-clearing

Subject Guidance

Computer Science at University

- ✓ You can find out more about different courses and entry requirements by exploring the UCAS Computer Science Guide online: https://www.ucas.com/ucas/subject-guide-list/computer-science
- ✓ You can find out more about the different careers by exploring the UCAS Careers portal online: https://www.ucas.com/ucas/after-gcses/find-career-ideas/explore-jobs

A Deeper Look Into Computer Science

- ✓ **Listen:** Podcast about IoT and AI https://www.iotforall.com/category/podcast/
- ✓ **Listen:** List of ML podcasts https://www.shopify.co.uk/partners/blog/machine-learning-podcast
- ✓ **Read:** Read about various sub-topics in Computer Science (use the search option or browse through the categories) https://medium.com/
- ✓ **Read:** Read about ML, AI etc. https://www.kdnuggets.com/
- ✓ **Browse:** Have a look through some AI talks https://www.computerworlduk.com/galleries/data/must-watch-ted-talks-on-ai-3652708/

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