2023-2024 ASSESSMENTS

Undergraduate

Workbook 1: Web Performance

SCC.306 Internet Applications Engineering

Recommended Completion Time [30 Hours]
Assessment Weighting [20%]

Academic Honesty and Integrity

Students at Lancaster University are part of an academic community that values trust, fairness and respect and actively encourages students to act with honesty and integrity. It is a University policy that students take responsibility for their work and comply with the university's standards and requirements- found in the Manual of Academic Regulations and Practice. By submitting their answers students will be confirming that the work submitted is completely their own. Academic misconduct regulations are in place for all forms of assessment and students may familiarise themselves with this via the university website: https://www.lancaster.ac.uk/academic-standards-and-quality/regulations-policies-and-committees/manual-of-academic-regulations-and-procedures/

Plagiarism

Plagiarism involves the unacknowledged use of someone else's work and passing it off as if it were one's own. This covers every form of submitted work, from written essays, video vignettes, and coding exercises. However, deliberately plagiarism with the intent to deceive and gain academic benefit is unacceptable. This is a conscious, pre-meditated form of cheating and is regarded as a serious breach of the core values of the University. More information may be found via the plagiarism framework website. All coursework is to be submitted electronically and will be run through our plagiarism detection mechanisms. Please ensure you are familiar with the University's Plagiarism rules and if you are in any doubt please contact your module tutor.
https://www.lancaster.ac.uk/academic-standards-and-quality/regulations-policies-and-committees/principles-policies-and-guidelines/plagiarism-framework/

Learning Outcomes

Details of the Learning Outcomes of this module can be found in the Module Programmes catalogue: https://portal.lancaster.ac.uk/intranet/mpc/modules/016886/000123. This tables specifies which learning outcomes are assessed and in which way they are assessed.

Subject Specific Learning Outcomes: Knowledge, Understanding and Skills		
Outcome	*Covered*	*How is it covered*
Understand web architectures, standards, and business practices.	Yes	Web architectures need to be understood to evaluate and assess performance.
Empirically assess the performance of a web site	Yes	Students need to quantify performance of websites themselves and use historical data to evaluate performance of a website in the context of a large number of users.
Understand and alleviate potential performance bottlenecks.	Yes	Students need to understand what potential changes should be made to websites in order to improve their performance.
Address issues and limitations of scale.	Yes	Students need to understand what potential changes should be made to websites in order to improve their scalability.
Accessibility and Internationalisation	No	
Design for Heterogeneous platforms (Responsive web design)	No	
Establish a quality process for web sites	No	
Security threats and hardening of web sites	No	
General Learning Outcomes: Knowledge, Understanding and Skills		
Outcome	*Covered*	*How is it covered*
Establish performance metrics	Yes	Students will need to identify and successfully use suitable metrics.
Interpret quantitative data to identify performance problems	Yes	Students need to quantitatively analyse data and draw conclusions from it about potential performance problems.
Make informed choices about complex distributed and networked architectures	No	

Feedback and Deadline

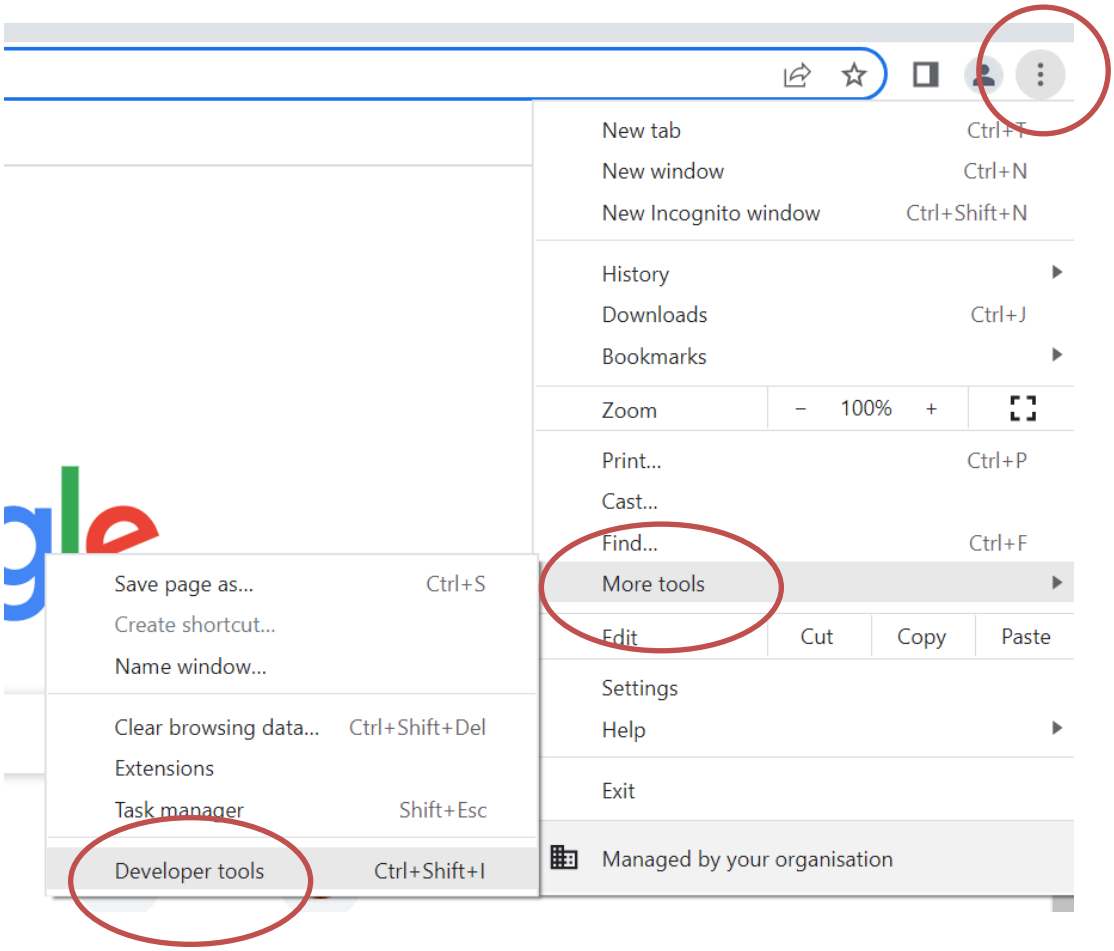
Feedback on this workbook will be provided continuously in the labs. Please ensure you attend them. The feedback on your submitted workbook will be a response to the entire cohort. If you wish to receive more detailed individual feedback, you will need to go through the cohort-wide feedback and identify and comment on which pieces of feedback do/do not apply to your work. You can then contact Phil and Matthew to discuss your comments on the feedback. The expected return of feedback is 4 weeks after the coursework deadline. The deadline for this work is **Friday 4pm Week 5**.

Introduction

In this workbook, you will be exploring measuring web performance yourself and using historical data to analyse web performance. **It is important that you read all instructions given in this coursework specification. Parts of this coursework rely on you using an external service. PLEASE READ the guidance on it, otherwise you may encounter issues in completing this coursework.**

Please note: Your results will be different depending on location, time, connection type, etc. This is interesting it itself and should be documented! But it isn't a problem – the coursework can be completed in the lab or at-home. If you see an unusual or unexpected result, please note that in your answer.

To complete this part of the coursework, you will be using the 'Google Chrome Development Tools' built into the Chrome browser.



You can access Developer Tools via the toolbar button, selecting 'More Tools' then 'Developer Tools'. A guide to using the tools can be found online at https://developer.chrome.com/docs/devtools/. You should try exploring the various features available in developer tools (particularly those under the network tab) before completing this coursework.

Submission

Once you are finished with both parts of this workbook, please submit this using the submission point provided in Moodle. Any SQL code should be included as text and not as a screenshot.

Part I

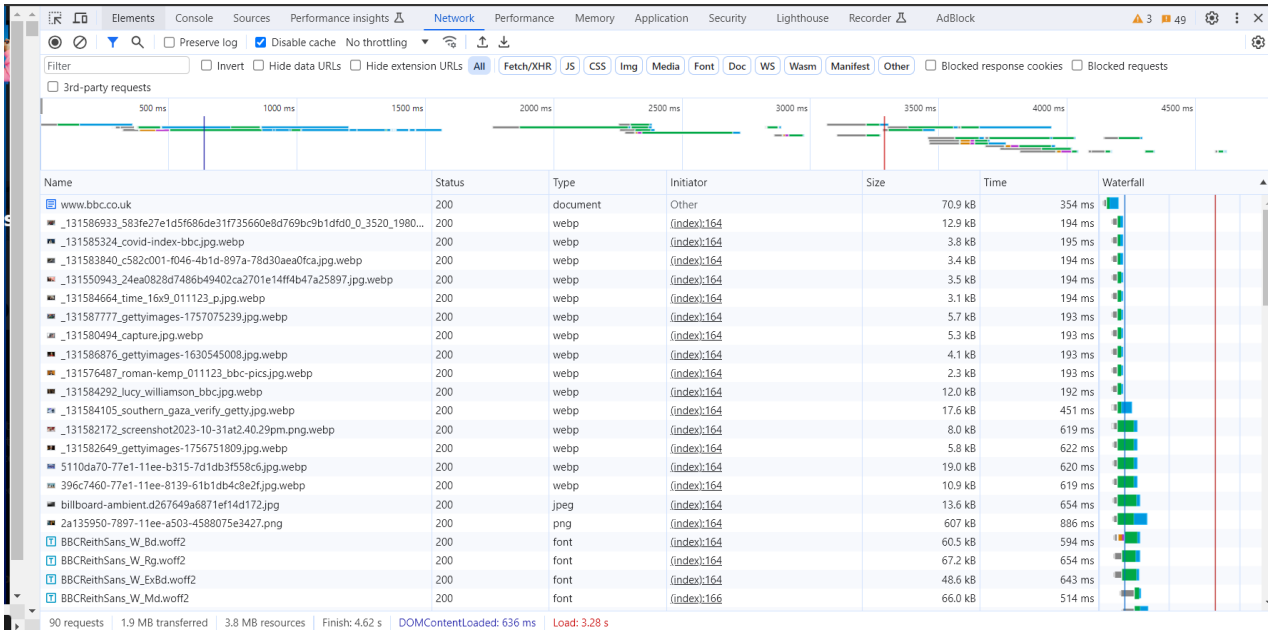
In this part of the coursework you will be expected to demonstrate an understanding of Web Performance based on material covered in the first two SCC.306 lectures.

Understanding Web Architecture

1. Using the Developer Tools, provide a screenshot of the waterfall for https://bbc.co.uk ensuring that the first 30-40 waterfall elements are clearly visible. It may be helpful to stop the capture at an appropriate point.

[2%]

Answer

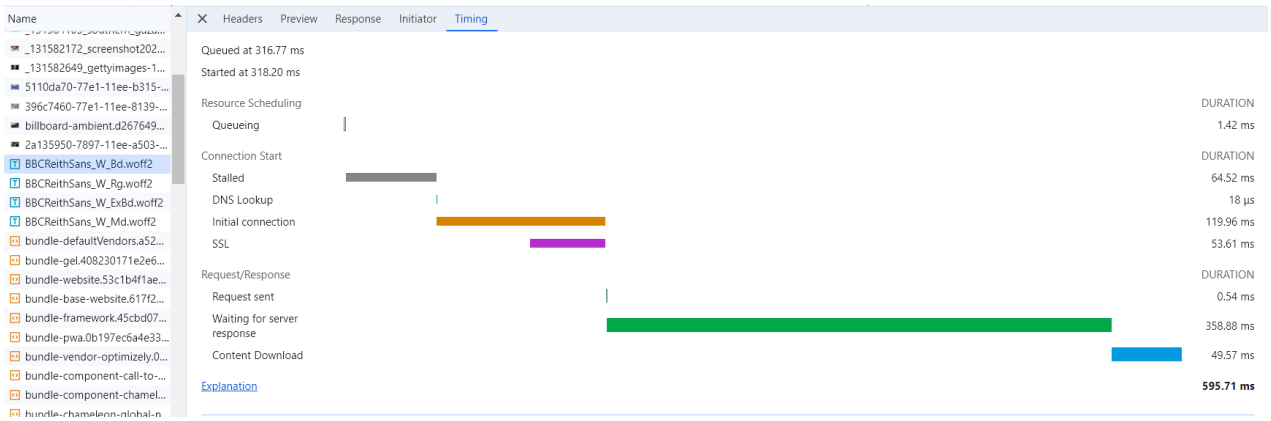


2. Select a **single resource** from the website that you captured in Q1. Explain and compare the significance in time required for each of the following items (relative to the total time for the retrieval of the resource).
    a. Stalled
    b. DNS Lookup
    c. Initial connection
    d. SSL
    e. Waiting for server response (TTFB)
    f. Content Download

    Provide a screenshot of the resource timings you are describing.

    [8%]

Answer



2a. The stalled time is the amount of time a resource is stalled or waiting. This can be due to things like queueing which prevent the resource from being loaded until previous more important resources have been loaded. The stalled time for this resource is 64.52ms

2b. The DNS lookup time is the time it takes for the server to find and resolve the IP address of the request message. The time is 18us probably due to bbc.co.uk being located in the UK.

2c. The initial connection time is the time it takes the browser to establish a connection with the request, performing all necessary operations such as TCP and SSL negotiation. The time here is 119.96ms.

2d. SSL is the security protocol that ensures all communication between server and client is secure, the time above is the time it takes to establish this protocol. The SSL negotiation tool 53.61ms

2e. TTFB stands for time to first byte, it is the time it takes for the browser to receive the first bit of a response from the recipient. The timing is 1 round trip plus the time the server needs to prepare the response. The time above is 355.88ms

2f. The content download time refers to the amount of time it takes the server to read the body of the response it receives. Larger times indicate a slow network or busy browser. The time it took was 49.57ms

The overall time to load the request was 595.71ms. All the above times are required in order for the element to load meaning they are all quite important, if the DNS or connection stages were dragged out the elements would never even be requested so they are the most important times. The other stages will just drag out the time it takes for the element to load which is equally inconvenient.

3. What factors could lead to an increase/decrease in each of the timings observed in Q2?

[10%]

Answer

Stalled

The Stalled time is affected by several factors including queuing, network latency, server processing and even client-side issues. The worse these components are the longer a resource can possibly stall for, if the server is already struggling to load more important elements above it will continually get worse for the elements below unless the server is optimised and the network is updated.

DNS Lookup

The DNS lookup time can be affected by the local DNS cache which allows a device to remember the DNS records of the resource meaning it doesn't need to look it up through DNS servers. Network latency can also affect DNS lookup time as bad paths or congestion can cause the lookup to take longer depending on their severity. The location of DNS servers compared to the physical location of the user can also affect this time, the closer the better.

Initial connection

The initial connection time is also affected by network latency, caching, geographical location and the DNS resolution time as above. It is also affected by the current load on the server and how many requests it must first deal with, the version of http being used and queues on the client side.

SSL

The SSL time can be affected by the speed of an SSL certificate, faster certificates take less time to perform handshakes which improve the loading of requests. Other factors include handshake compression(compressing handshake messages), the negotiation during the hello phases of both the client and server, network latency and server side caching of SSL session data from previous visits to the site.

Waiting for server response (TTFB)

The time to first byte is affected by many of the same elements as the initial connection stage depending mainly on the server and its capabilities, the client and their caching and queues and the network and its latency and congestion.

Content Download

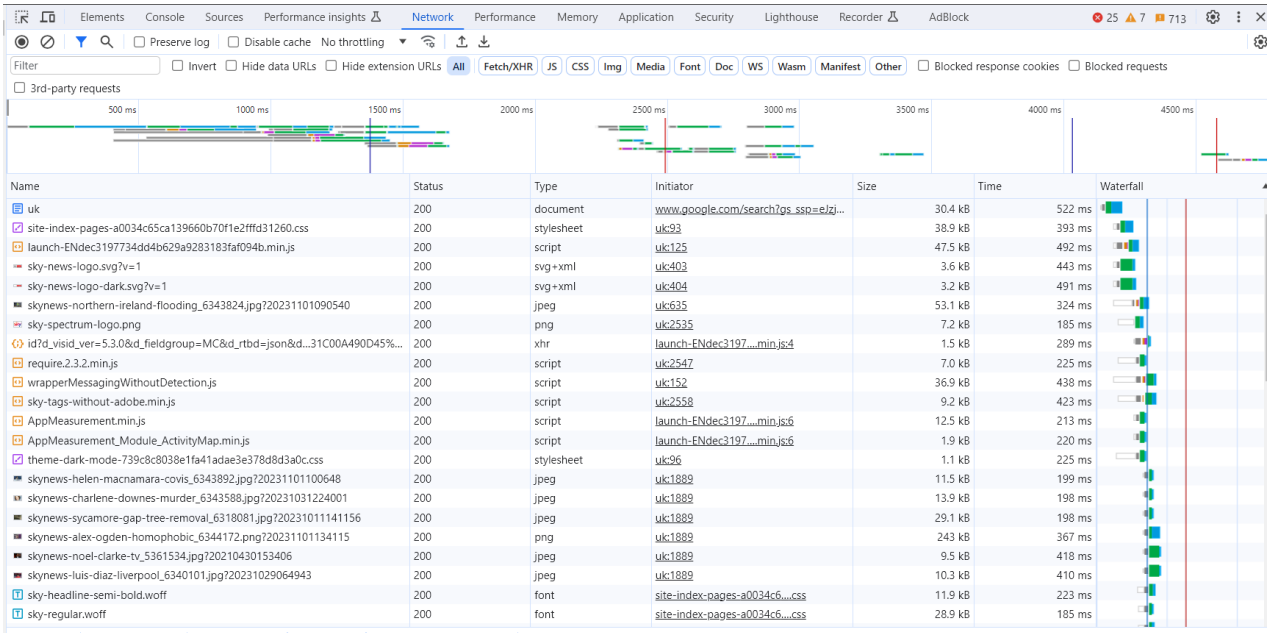
Very similar to the above, we can however preload critical elements and download multiple elements in parallel to speed up the process. Optimising resources ordering and loading is the best way to reduce content download time.

4. It is common for the retrieval process of a website to differ between the first and subsequent visits. Demonstrate this behaviour by comparing **two waterfall** screenshots and **identify which resources** are affected by this and **explain why**.

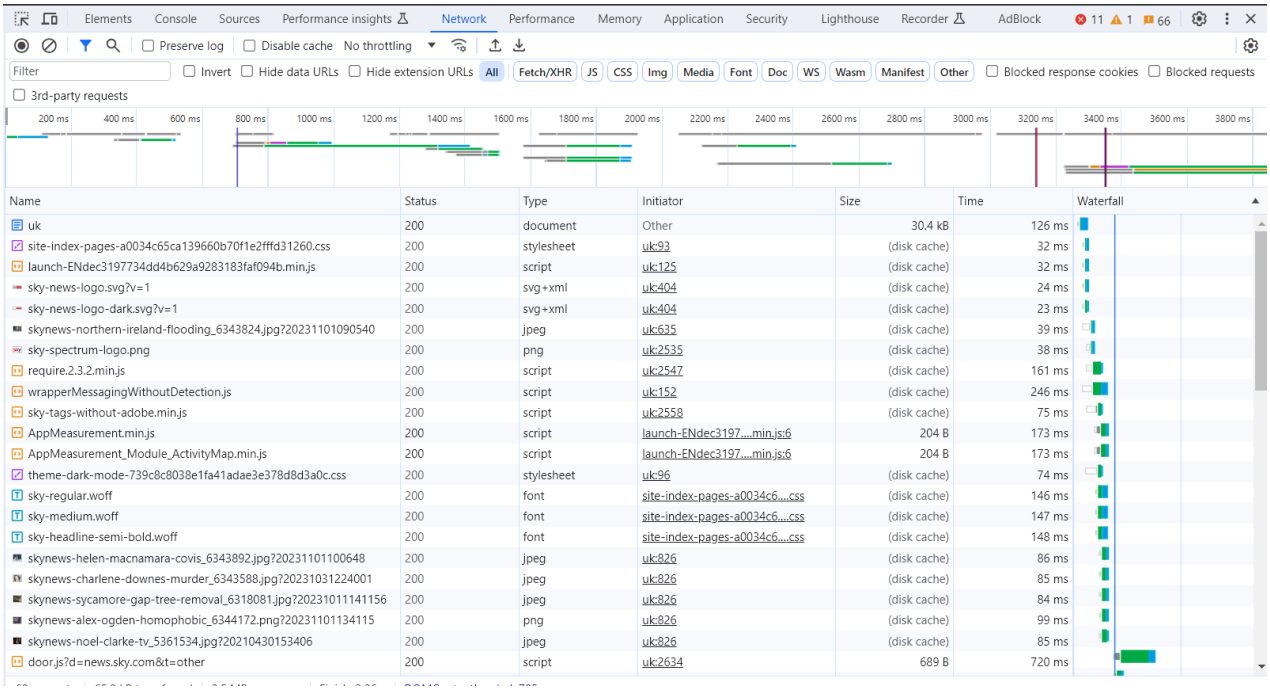
[5%]

Answer

First Visit:



Second Visit:



As you can see above almost all of the resources first loaded in the waterfall have much faster loading times than before. This is due to things like caching as described above, the server/client store information about each element so they can be quickly retrieved without as much lookup time on subsequent visits to the site.

5. Calculate two appropriate statistics that summarise the start render times for the following web pages:

- https://bbc.co.uk
- https://lancaster.ac.uk
- https://amazon.co.uk

Provide all the data used to make this calculation in the box below. Describe your methodology for gathering this data.

[5%]

Answer

BBC:
Values: 319ms, 289ms, 262ms, 253ms, 278ms
Mean: 280ms Median: 278ms

Lancaster:
Values: 433ms, 338ms, 339ms, 232ms, 377ms
Mean: 343ms Median: 339ms

Amazon:
Values: 736ms, 708ms, 768ms, 617ms, 707ms
Mean: 707ms Median: 708ms

To gather this data, I made sure to visit these pages from the same device, at the same time, ensuring like for like conditions to make the data as accurate as possible. I gathered a sample of 5 visits to each site to make sure the data set was large enough to get an accurate result. I am using the DOMContentLoaded time from the performance tab of the dev tools as the documentation states the DOMContentLoaded event is when the html has been fully parsed and all deferred scripts have been downloaded and executed (MozDevNet). Cache has also been disabled for all visits of each page.

6. Explain why the descriptive statistics you selected in Q5 are appropriate to use. Are there any other measures that should be presented with these statistics?

[5%]

Answer

The DOM content loaded time is suitable as it is the time it takes for the HTML of the site to be fully loaded and parsed correctly, giving way for the DOM to start building the webpage properly without having to know the actual size of elements that haven't been loaded yet. Without the DOM loaded elements would have no structure and the web page would look much messier which is why it is loaded first with the HTML. The mean of this time is a suitable statistic to calculate the start render time as it takes the average of a set of visits to these individual sites giving a baseline for what could be expected when visiting the site from a device in a similar locale and of similar spec. The median is also suitable as it takes the middle value from this range of values giving us a middle ground that is unaffected by potential outliers that could tamper with the mean. Another statistic to consider would be the first contentful paint timing which shows the exact moment the first interactive/visual element on the page is loaded.

7. With reference to the DOM and the order in which resources have been obtained, what do you consider to be responsible for any differences observed in the start render times of the websites in Q5?

[5%]

Answer

The sites above have all quickly fully loaded their html and then subsequently loaded any styling information needed for this HTML and any assets the page requires. The differences between the sites for the start render times mainly depends on the size of the HTML and CSS files as the larger they are and the more HTML the site has to support, the longer it will take to fully download. The sites amazon and BBC load their HTML first meaning their start renders are all within the first element in their waterfall so the differences between start render times likely aren't due to any ordering issues. In the case of Lancaster the HTML was actually the second element loaded, with a non-visual element being loaded first meaning there is an extra step involved before the start render time. Amazon has a much longer DOM time most likely due to the amount of elements that would need to be loaded and to ensure that the formatting is guaranteed before the page begins loading any additional elements, they also would have to pull these elements live and tailor them to the user which the other sites do not, BBC will pull live articles but these are standard for everyone and not user focused.

8. Does https://lancaster.ac.uk use any techniques mentioned in the week 1 lecture to optimize its performance? If so, list them below (use code extracts where appropriate as evidence to assist your explanation).

[5%]

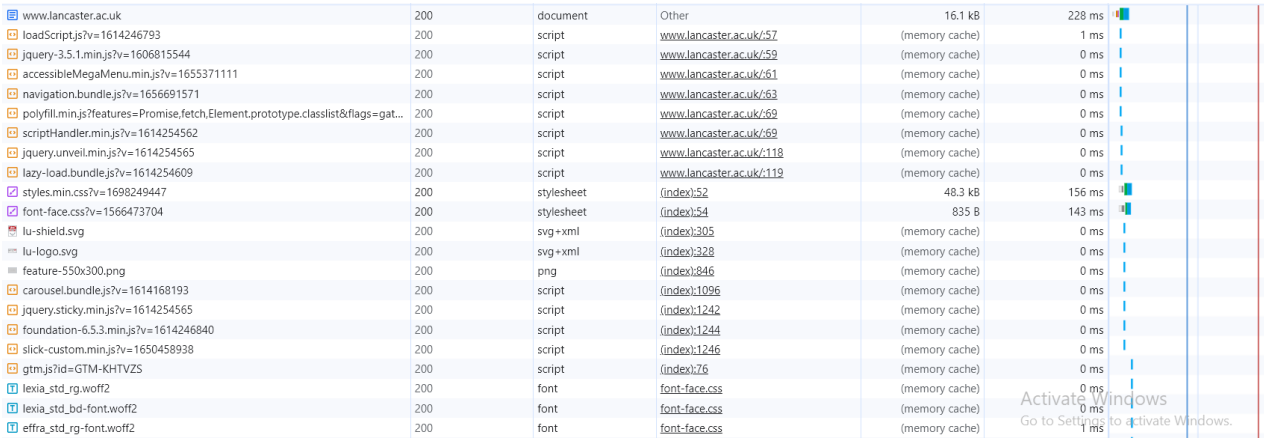
Answer

Lancaster puts the CSS in the head so it is loaded first for the DOM so no content is blocked from loading:

```
<title>Home - Lancaster University</title>
<!-- Siteimprove hook -->
<meta name="PageID" content="272">
<!-- meta description -->
<meta name="description" content="Lancaster University is among the best in the UK. A Top 15 university in the UK league tables, we are also highly ran
ed in international league tables such as the QS World Rankings.">
<!-- css: app.css -->
<link rel="stylesheet" type="text/css" media="screen, print" href="/media/lancaster-university/style-assets/css/styles.min.css?v=1698249447">
<!-- font-face.css -->
<link rel="stylesheet" type="text/css" media="screen" href="/media/lancaster-university/style-assets/css/font-face.css?v=1566473704">
<!-- loadscript -->
<script async src="https://www.googletagmanager.com/gtm.js?id=GTM-KHTVZS"></script>
<script type="text/javascript" src="/media/wdp/style-assets/javascript/lib/loadScript.js?v=1614246793"></script>
<!-- jquery -->
<script type="text/javascript" src="/media/wdp/style-assets/javascript/lib/thirdparty/jquery/jquery-3.5.1.min.js?v=1606815544"></script>
<!-- adobe mega menu plugin -->
<script type="text/javascript" src="/media/wdp/style-assets/javascript/lib/thirdparty/accessibleMegaMenu.min.js?v=1655371111"></script>
<!-- navigation -->
<script type="text/javascript" src="/media/wdp/style-assets/javascript/compiled/jspm/navigation.bundle.js?v=1656691571"></script>
<!-- favicon -->
<link rel="shortcut icon" href="/media/lancaster-university/style-assets/images/favicon.ico">
<link rel="apple-touch-icon" href="/media/lancaster-university/style-assets/images/apple-touch-icon.png">
<!-- included head code -->
```

The above shows linked CSS sheets contained within the head of the HTML of Lancaster.ac.uk.

CSS links are also used to combine multiple files into one link to remove duplicates, also seen above.



www.lancaster.ac.uk	200	document	Other	16.1 kB	228 ms	
loadScript.js?v=1614246793	200	script	www.lancaster.ac.uk/:57	(memory cache)	1 ms	
jquery-3.5.1.min.js?v=1606815544	200	script	www.lancaster.ac.uk/:59	(memory cache)	0 ms	
accessibleMegaMenu.min.js?v=1655371111	200	script	www.lancaster.ac.uk/:61	(memory cache)	0 ms	
navigation.bundle.js?v=1656691571	200	script	www.lancaster.ac.uk/:63	(memory cache)	0 ms	
polyfill.min.js?features=Promise,fetch,Element.prototype.classlist&flags=gat...	200	script	www.lancaster.ac.uk/:69	(memory cache)	0 ms	
scriptHandler.min.js?v=1614254562	200	script	www.lancaster.ac.uk/:69	(memory cache)	0 ms	
jquery.unveil.min.js?v=1614254565	200	script	www.lancaster.ac.uk/:118	(memory cache)	0 ms	
lazy-load.bundle.js?v=1614254609	200	script	www.lancaster.ac.uk/:119	(memory cache)	0 ms	
styles.min.css?v=1698249447	200	stylesheet	(index):52	48.3 kB	156 ms	
font-face.css?v=1566473704	200	stylesheet	(index):54	835 B	143 ms	
lu-shield.svg	200	svg+xml	(index):305	(memory cache)	0 ms	
lu-logo.svg	200	svg+xml	(index):328	(memory cache)	0 ms	
feature-550x300.png	200	png	(index):846	(memory cache)	0 ms	
carousel.bundle.js?v=1614168193	200	script	(index):1096	(memory cache)	0 ms	
jquery.sticky.min.js?v=1614254565	200	script	(index):1242	(memory cache)	0 ms	
foundation-6.5.3.min.js?v=1614246840	200	script	(index):1244	(memory cache)	0 ms	
slick-custom.min.js?v=1650458938	200	script	(index):1246	(memory cache)	0 ms	
gtm.js?id=GTM-KHTVZS	200	script	(index):76	(memory cache)	0 ms	
lexia_std_rg.woff2	200	font	font-face.css	(memory cache)	0 ms	
lexia_std_bd-font.woff2	200	font	font-face.css	(memory cache)	0 ms	
effra_std_rg-font.woff2	200	font	font-face.css	(memory cache)	1 ms	

Lancaster also supports caching as seen above.

9. What optimizations *could* be made to the Lancaster University website and how would they be beneficial?

[5%]

Answer

The Lancaster university page could be optimised by making the page and its elements smaller in size. The first page we see has a lot of information that seems unnecessary and could potentially be moved onto other separate pages so that we can quickly load the first page in its entirety before loading any other elements we do not currently need in the background. By decreasing the size of some of the elements this will also reduce the time it takes for elements to load and will get the page up quicker. We could also use the YUI image loader to delay the loading of components until they are within view of the user as there is a lot of stuff to scroll through on the site that may not be seen by most users.

Part II

Getting started

This next section involves the 'Chrome User Experience Report' (CrUX), which provides user experience metrics for many websites. This service aggregates multiple visits from users, to gain a comprehensive performance overview of websites within different environments. More information can be found at the following URL:
https://developer.chrome.com/docs/crux/

You will be using the Google BigQuery API, which allows you to query the vast database with standard SQL. A step-by-step guide on how to access this service is located here:
https://developer.chrome.com/docs/crux/bigquery/#accessing-the-dataset-in-gcp

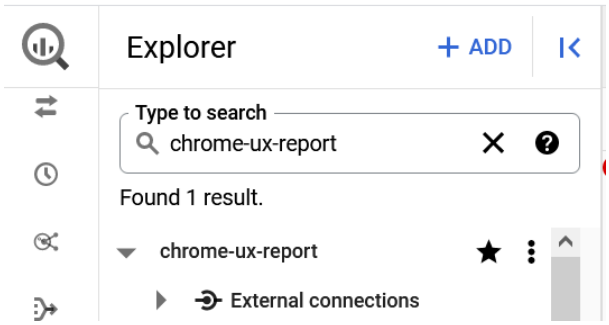
Details on the schema of the data is available here:
https://developer.chrome.com/docs/crux/bigquery/#detailed-table-schema

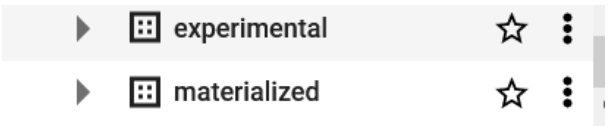
A guide on accessing CrUX via BigQuery can be accessed at:
https://web.dev/chrome-ux-report-bigquery/

You can access BigQuery at this URL:
https://cloud.google.com/bigquery/

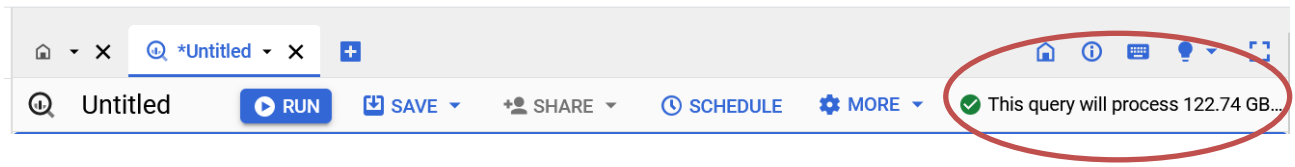
Please read this documentation carefully and run some of the examples given. This will ensure that everything is setup as intended and you have started to build the understanding of both the tools and the dataset required to complete this part of the workbook.

You can use Explorer to find the available CrUX tables that you can query. Scroll all the way down as the experimental and materialized tables may be useful in constructing your queries.





Please note that there are data limits of 1TB a month. Ensure that your queries are properly written before running them to avoid being prevented from running further queries due to BigQuery rate limiting your account**. Do not run any query over 125GB (Q1) or 50GB** as all questions have been crafted to not need such a large amount of data queried. Always check the amount of data that will be queried.



Please be aware that BigQuery can charge credit cards attached to your Google account. Do not exceed the free 1TB included per month.

In your answers make sure that you:

1. Read and answer all components of the entire question.
2. Check that the data returned from queries matches your expectations. If you do not understand what format the data is in, re-read the BigQuery documentation.
3. If a query has not worked, think about why this is the case before making changes and re-running the query. You have limited quota, ensure that you use it effectively.
4. Are specific in your analysis of the data. Do not use words such as “most” and “relatively”, state specific statistics that you have extracted from the data.
5. Do not assume the behaviour of graphing tools. Look at their documentation to ensure you are using the correct tool.
6. When asked to refer to the data, it may be beneficial to include a visualisation of the data. Do not forget to state statistics in your written answer.

Google Cloud Education Credits

We have Google Cloud Education Credits available for use. You can redeem these using this link: https://vector.my.salesforce-sites.com/GCPEDU?cid=orsV78HcIfyM2GUDwJaAY6BoqDWYnJehcoS9lHNpPgy4JPpYVrnHMqmNvySPmWXQ/

You will be asked for a name and an email address. Your email address must be your @lancaster.ac.uk address. This means that you must create a Google account using your Lancaster email.

- A confirmation email will be sent to you with a coupon code.
- You can request a coupon from the URL and redeem it until: 16/2/2024.
- Coupon valid through: 16/10/2024.
- You can only request ONE code per unique email address.

If you encounter any issues with the process, please contact Matthew (m.s.bradbury@lancaster.ac.uk) with details of the error you encounter.

The value of these coupons is $50 USD. **If you use the whole of this voucher, then you will be charged to the credit card associated with your account**. Please ensure that you do not go over this amount.

Questions

1. Using BigQuery, create an SQL statement which will retrieve the data required to visualise a histogram of **DOMContentLoaded** in the month of **June 2023** for https://tv.apple.com. Enter the statement in the answer box below and include the first 15 rows of data returned.

[5%]

Answer

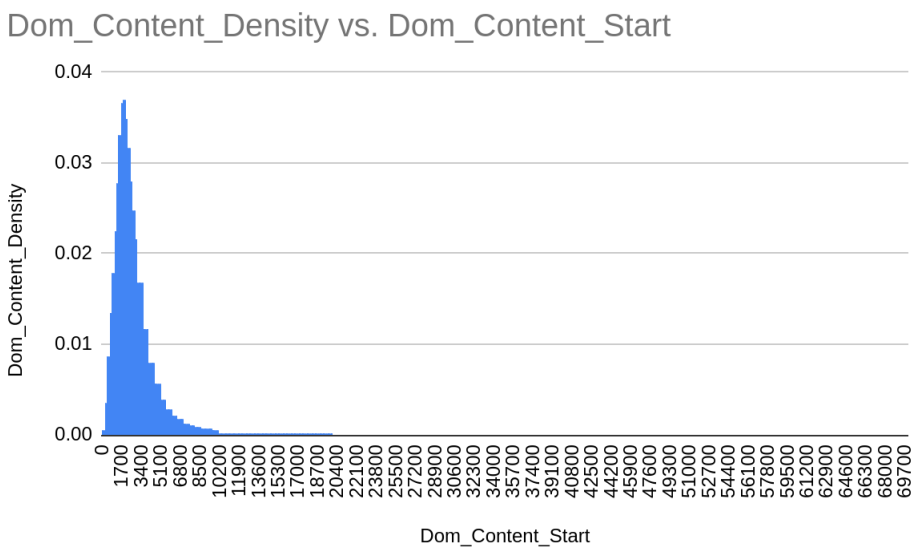
```
SELECT
BIN.start,
SUM(BIN.density)
FROM
`chrome-ux-report.all.202306`,
UNNEST(dom_content_loaded.histogram.bin) AS BIN
WHERE
origin = 'https://tv.apple.com'
GROUP BY
BIN.start
ORDER BY
BIN.start ASC;
```

Row	DomContentStarted	DomContentDensity
1	0	0.00055
2	100	0.00055
3	200	0.00355
4	300	0.00355
5	400	0.0086
6	500	0.0086
7	600	0.01345
8	700	0.01345
9	800	0.01795
10	900	0.01795
11	1000	0.0225
12	1100	0.0225
13	1200	0.0278
14	1300	0.0278
15	1400	0.03315

2. Using the data retrieved in the previous question, **visualise the histogram** using Excel (or any other tool of your choosing), and include a screenshot of the histogram in the box below. Ensure that the histogram includes appropriate detail to facilitate interpreting the data presented.

[5%]

Answer



3. What information can be inferred from the histogram? Why is this information beneficial to website developers? How does this differ to the waterfall model (in Q1 of Part I)?

[10%]

Answer

The histogram above shows the relative number of users that are reaching Dom_Content_Loaded from the beginning of entering a page to when their page has loaded. The compiled values show that most sites and users load around the 3000-5000ms range. It also shows that the Dom Density severely drops off after this, suggesting that most users/sites do not take more than 20400ms to fully load. This information is beneficial to web designers as it can be used to evaluate the load times of their sites for a range of users instead of just the single user view as recorded above in the Q1 waterfall. Designers could use it to see which of these pages load quickest and then take elements from these sites to optimise their own. The histogram cuts of at a certain point as the DOM density becomes so low it is practically 0 and so doesn't show up with this scale.

4. Write an SQL statement which demonstrates the evolving usage of form factors through which people access websites (Phone, Tablet, Desktop) for people in **Poland** and **Malaysia** who visit https://www.tiktok.com. Show how this has changed each year from **2021** to **2023 (inclusive)**,

using **March** as the reference month in each case. Enter the statement in the answer box below and include the first 15 rows of data returned. Select all density for each

[5%]

Answer

```
SELECT
country_code AS Country,
yyyymm AS Dates,
sum(desktopDensity) AS Desktop_Density,
sum(phoneDensity) AS Phone_Density,
sum(tabletDensity) AS Tablet_Density
FROM
`chrome-ux-report.materialized.country_summary`
WHERE
origin = 'https://www.tiktok.com' AND (country_code = "pl" OR country_code = "my")
AND yyyymm IN (202103,202203,202303)
GROUP BY
country_code, yyyymm
ORDER BY
yyyymm ASC
```

Row	Country	Dates	Desktop_Density	Phone_Density	Tablet_Density
1	my	202103	0.3582	0.6412	0.0
2	pl	202103	0.6141	0.386	0.0
3	my	202203	0.1949	0.8052	0.0
4	pl	202203	0.2891	0.7109	0.0
5	pl	202303	0.2638	0.7361	0.0
6	my	202303	0.1598	0.8399	0.0

5. Describe the trends that can be observed from the data returned in Q4. As someone responsible for the optimisation of the website and its supporting infrastructure, what useful findings can you infer from this result? Be specific in terms of changes that could be made. **Refer to the data** to support your conclusions.

[10%]

Answer

The results above show a heavy preference in user density for phone use of tik tok. Since the site is mainly marketed as an app these trends make sense, there is an outlier for desktop use in Poland in 2021/03 but this is quickly overrun by mobile use of the site. We can also see that tablet use is 0.0 in all years which is most likely due to how content is displayed on tablets. Tablets display TikTok in a minimised screen replicating the mobile view which is why their usage is compounded with mobile density. In terms of changes a developer could make it would be to potentially make a tablet specific view for a more optimal viewing experience on those devices. They could also focus on making more optimisations to the mobile side of things as that is where the majority of their users will reside.

6. Using the **United States, Madagascar,** and an **additional country of your choice**, write an SQL statement which compares the density of users who visit https://www.nytimes.com in January 2023 and where DOMContentLoaded occurs in 2.2 seconds or less. Enter the statement in the answer box below and include the first 15 rows of data returned.

[5%]

Answer

```
SELECT
country_code AS Country,
SUM(BIN.density) AS User_Density,
FROM
`chrome-ux-report.experimental.country`,
UNNEST(dom_content_loaded.histogram.bin) AS BIN
WHERE
origin = 'https://www.nytimes.com'
AND (country_code = "us" OR country_code = "mg" OR country_code =
"pl")
AND yyyymm = 202301
AND BIN.start <= 2200
GROUP BY
country_code
```

Row	Country	User_Density
1	mg	0.43749999999999989
2	pl	0.86444999999999983
3	us	0.87965

7. Again, describe the trends that can be observed from the data returned in Q6. As someone responsible for the optimisation of the website and its supporting infrastructure, what useful findings can you infer from this result? Be specific in terms of changes that could be made. **Refer to the data** as required to support your conclusions.

[10%]

Answer

The above results demonstrate a heavy preference to users in Poland and the US. A larger DOM density in the first 2.2 seconds or less in the US makes sense due to the site being based in America, meaning the servers will be closer to users and therefore will load much quicker than somewhere like Madagascar. It shows that the US and Poland must also have strong network infrastructures as they have above 80% user density in the first 2.2 seconds, this suggests not much needs to be done in terms of optimisation of the site and it may just be due to individual user devices. The results for Madagascar suggest that they struggle to create reliable connections to the site and indicates a weaker network infrastructure overall. The DOM density is only 0.437 in the first 2.2 seconds suggesting longer load times, developers could focus on trying to optimise this but seeing as Poland and the US have similar results this may not change the timing much.

References:

MozDevNet (no date) *Document: Domcontentloaded event - web apis: MDN*, *Web APIs | MDN*. Available at: https://developer.mozilla.org/en-US/docs/Web/API/Document/DOMContentLoaded_event (Accessed: 03 November 2023).