

Paper - I

This article was co-authored by Rohini Lakshané and Prateek Waghre. It was published on 28th, January 2020.¹

Analysis of URLs Whitelisted in Jammu and Kashmir

The Supreme Court gave a [judgement](#) on January 10, 2020 directing the Central government to review the total suspension of Internet services in Jammu and Kashmir imposed since August 5, 2019 and to restore essential services. In response, the government of Jammu and Kashmir [issued a whitelist](#) comprising 153 entries on January 18, and increased the [number of entries to 301](#) on [January 24](#). What would the experience of an ordinary resident of Jammu and Kashmir be like under the whitelist arrangement? We conducted a preliminary analysis to empirically determine whether the 301 whitelisted websites and services would be practically usable and found that **only 126 were usable to some degree**.

Before we delve further into the [questions the list raises](#), [the role of ISPs](#), and [analyse the list itself](#), it is pertinent to understand the background and context in which an ordinary resident of Jammu and Kashmir may access the Internet. India has experienced the [highest number](#) of intentional [Internet shutdowns](#) across the world since 2012. . Kashmir [has been facing](#) the [longest intentional Internet shutdown ever](#) recorded in a democratic country. Voice and SMS functionality, without Internet connectivity, was reactivated on postpaid mobile connections in Jammu and Kashmir on [October](#) 14, 2019. People in the Kashmir valley can access the Internet only through the 844 kiosks run by the government.

Under three orders (dated January [14](#), [18](#) and [24](#)) issued by the government of Jammu and Kashmir:

1. 2G Internet connectivity would be reinstated on postpaid mobile connections in 10 districts of Jammu Division and 2 of Kashmir Division.
2. “The internet speed shall be restricted to 2G only.”
3. 400 additional Internet kiosks are to be installed in Kashmir.
4. Social media websites, peer-to-peer (P2P) communication apps, and Virtual Private Networks (VPNs) services have been explicitly prohibited.
5. ISPs are to provide wired broadband to companies engaged in “Software (IT/ ITES) Services”.

¹<https://www.medianama.com/2020/01/223-analysis-of-whitelisted-urls-in-jammu-and-kashmir-how-usable-are-they/>

6. For wired connections, Paragraph II of the order dated January 24 states, “For fixed line Internet connectivity: Internet connectivity shall be *[made]* available only after Mac-binding.”
7. Voice and SMS functionality would be restored on prepaid mobile connections across all districts of Jammu and Kashmir.
8. For providing internet access on locally-registered pre-paid mobile connections, telecom service providers or “TSPs shall initiate a process of verification of credentials of these subscribers as per the norms applicable for postpaid connections”.
9. “The ISPs shall be responsible for ensuring that access is allowed to whitelisted sites only.”
10. The order dated January 14 states that it “may be subject to further revision” after which the department would conduct “a review of the adverse impact, if any, of this relaxation on the security situation.” According to the order released on January 24, “the law enforcement agencies have reported no adverse impact so far. However, they have expressed apprehension of misuse of terror activities and incitement of general public...”
11. “Whitelisting of sites shall be a continuous process,” which could be interpreted to mean that the government would periodically update the list.

Thus, an ordinary internet user in Jammu and Kashmir accessing the Internet under this whitelist arrangement would be doing so via 2G mobile connections or Internet kiosks placed inside government offices.

Questions raised by selection of entries in the whitelist

1. In the orders dated January 14 and 18, the Government of Jammu and Kashmir cites the use of the Internet for the following activities as some of the reasons for implementing the total Internet blackout in Kashmir: “terrorism/terror activities”, activities of “anti-national elements”, “rumour-mongering”, “spread of propoganda/ ideologies”, “targeted messaging to propagate terrorism”, “fallacious proxy wars”, “causing disaffection and discontent” among people, and the “spread of fake news”. In light of this explanation, what were the process and criteria applied to select these specific URLs/ services/ websites to be on the whitelist?
2. What were the process and criteria, if any, to reject websites and services that are similar to those whitelisted and those that provide the same or comparable services? For example, some travel aggregator websites (MakeMyTrip, Goibibo, Cleartrip, Trivago, Yatra, etc) have been included but not others (Agoda, Expedia, Kayak, Hotels.com). Online shopping/e-commerce websites Flipkart, Amazon, Myntra and Jabong feature in the whitelist but not Snapdeal, Ebay, and others.
3. How were the residents of Jammu and Kashmir informed about this whitelist, that these specific services/ websites had become accessible? News websites and social media websites are still blocked. The orders will appear in an issue of the gazette, which is just one source of information and not accessible by everybody.

4. In view of all the above questions, how do the authorised government officers “ensure implementation of these directions in letter and spirit”, as stated in paragraph 7 of the order dated January 14?

Role of Internet Service Providers (ISPs)

The whitelist and its accompanying orders raise some concerns about ISPs’ implementation of the whitelist.

1. In the case of the entries that contain neither URLs nor qualifying information about including subdomains or about permitting mobile applications, it should not be left to the discretion of an Internet Service Provider (ISP) to determine the appropriate URLs or the appropriate mode of access (mobile or desktop application, mobile or desktop version) of a whitelisted service or website. ISPs are intermediaries and are not authorised to take a judgement call on the orders they receive from the government. Moreover, the whitelist orders explicitly state that the onus of ensuring that sites outside the whitelist remain inaccessible is on the ISPs (“The ISPs shall be responsible for ensuring that access is allowed to whitelisted sites only.”)
2. In the case of invalid or indeterminate URLs, how are whitelisted entries to be implemented? What are the options for an ISP to seek clarifications about these from the government?
3. ISPs have been directed to provide wired broadband to companies in Jammu and Kashmir engaged in “Software (IT/ ITES) Services”. In view of the fact that the terms IT (information technology) and ITES (information technology enabled services) cover a broad range of commercial activities, how is this directive going to be operationalised?
4. In a recently published [paper](#) analysing how ISPs in India block websites, researchers at the Centre for Internet and Society (CIS) found that ISPs and governments were not willing to disclose the URLs that were blocked. The study also found that less than 30% blocked URLs were common across the ISPs included in the study, and different ISPs used different techniques to implement blocklists. This is indicative of arbitrary action on the part of individual ISPs. It is also likely that Internet users have limited recourse owing to the lack of transparency in censoring websites. When combined with the need for ISPs to exercise their own discretion/ judgement in implementing these orders (as argued in 1), there is plenty of potential for inconsistent enforcement by ISPs.
5. It is unclear how ISPs will actually implement this whitelist. If the filtering is done at the DNS layer, then the number of practically unusable websites will likely be higher than what we encountered, since the [DNS resolution](#) process itself is likely to be broken for any website that returns anything other than an A record/ IP Address.

Findings and Analysis

1. Entries with no URL

1. Media service providers/streaming services: There are 7 streaming services on the list: Amazon Prime, Netflix, Sony Liv, Zee 5, Hotstar, Voot, and Airtel TV. They support viewing on desktop browsers and mobile apps. This may be a reason why the whitelist only states their names and not the corresponding URLs. Assuming that these services are enabled for use on both desktop and mobile applications, they will still be practically unusable because:

1. Only 2G speeds are currently permitted in Jammu and Kashmir. 2G speeds are too slow for streaming audio-video and multimedia content.
2. Streamed content is delivered over CDN (content delivery network) URLs, none of which are present on the current whitelist.

2. JioChat: JioChat is an iOS and Android instant messaging app that supports voice and video calling. It is the only service on this whitelist that supports these functionalities. It is unlikely that this app would be practically usable for video/voice calls because 2G speeds are too slow for it.

2. Government-owned eTLDs

The whitelist includes three entries for government-owned eTLDs (effective top-level domains, also known as “public suffixes”): “Gov.in”, “Nic.in” and “Ac.in”. The entries do not contain URLs or qualifying information about including subdomains. It should be explicitly stated if ISPs are expected to allow gov.in, nic.in, ac.in and all their subdomains. For example, gov.in houses [four levels of subdomains](#). Currently, it is unclear how ISPs will interpret and implement this since the entries in the whitelist do not contain adequate information. The directory of Indian government websites is available at <http://goidirectory.nic.in>.

3. Banking and Finance Services

Log-in pages are on domains or subdomains different from those listed in the whitelist, which is why these services are not practically useful regardless of whether the actual whitelisted URL is accessible/usable. For example,

1. The website of ICICI Bank <https://www.icicibank.com> is whitelisted. However, the URL to log-in to personal banking at ICICI is on a subdomain of the website, <https://infinity.icicibank.com>, which is not whitelisted. So, individuals with an account at ICICI Bank, will not be able to access their accounts online.
2. While <https://www.hdfc.com> has been whitelisted, HDFC Bank’s personal banking services are on a different domain, <https://www.hdfcbank.com>, which will also remain inaccessible.

VPNs and proxy services are prohibited, so an ordinary user would be unable to circumvent restrictions imposed by the whitelist.

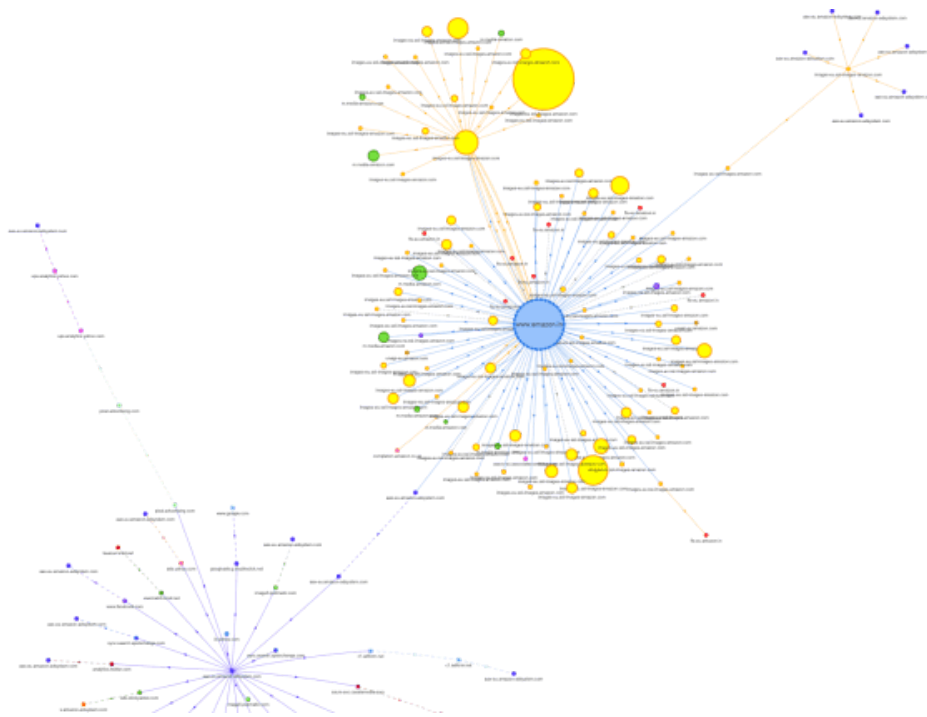
Of the 15 websites categorised under “Banking” in the whitelist, only 2 (www.jkbankonline.com and www.westernunion.com) had accessible log-in pages/sections and all 15 had at least one identifiable issue when they were accessed with the whitelist restrictions in place.

4. CDN, Sub-Domains, and Third-Party Content

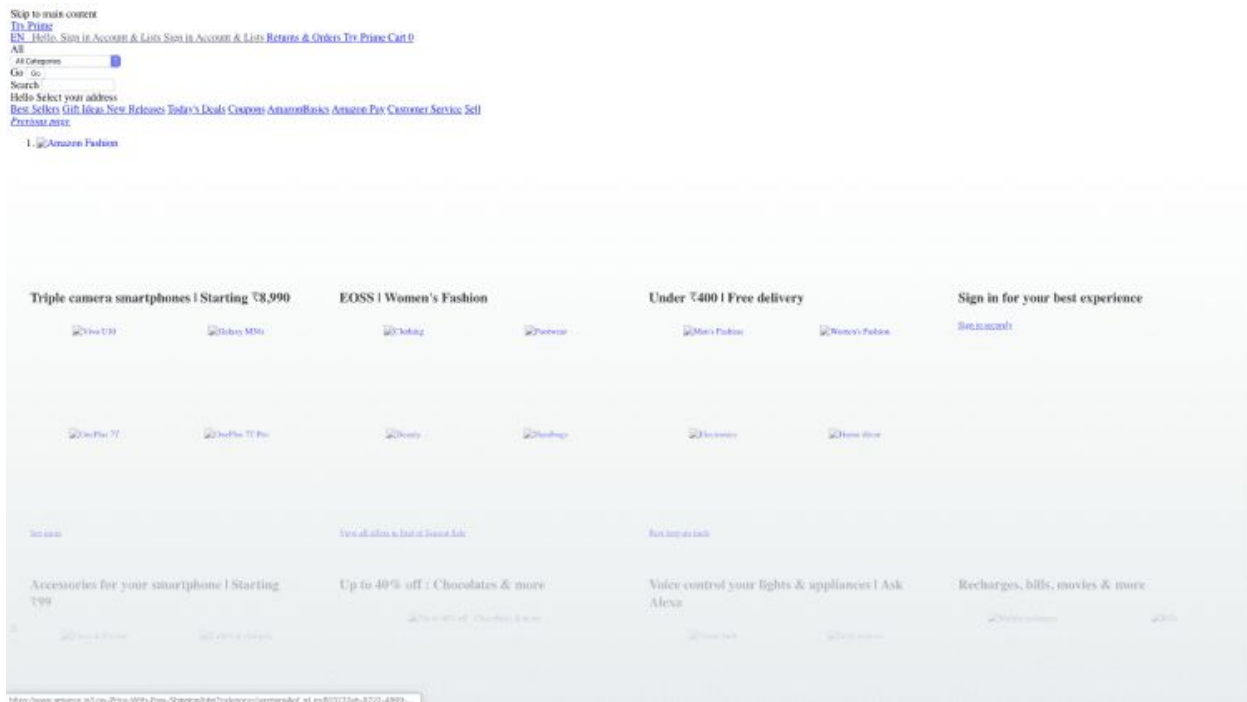
The [State of the Web](#) maintained by http Archive indicates that the median number of requests on a webpage for mobile devices is approximately 70. These requests are spread across subdomains of the website, domains owned by content delivery networks (CDNs) such as akamaized.net, cloudfront.net, cloudflare.net, etc. and third-party domains such as Google Analytics, tag managers, real user monitoring tools, advertisers and so on. The whitelist approach interferes with these requests and more often than not, results in an adverse impact on the functioning of the website itself. In our analysis, we observed that this affected websites to varying degrees:

1. Minimal visible impact
2. Some images don't load
3. All images don't load
4. Critical functions become unresponsive, such as , search in the case of some OTAs (online travel agents)
5. The entire layout scheme breaks

Example 1: Consider www.amazon.in. The [request map](#) shows that a significant number of requests are made to domains other than www.amazon.in. Since these requests will be blocked, the website will barely function for the user accessing behind the whitelist. This is evident from the screenshot of the landing-page.

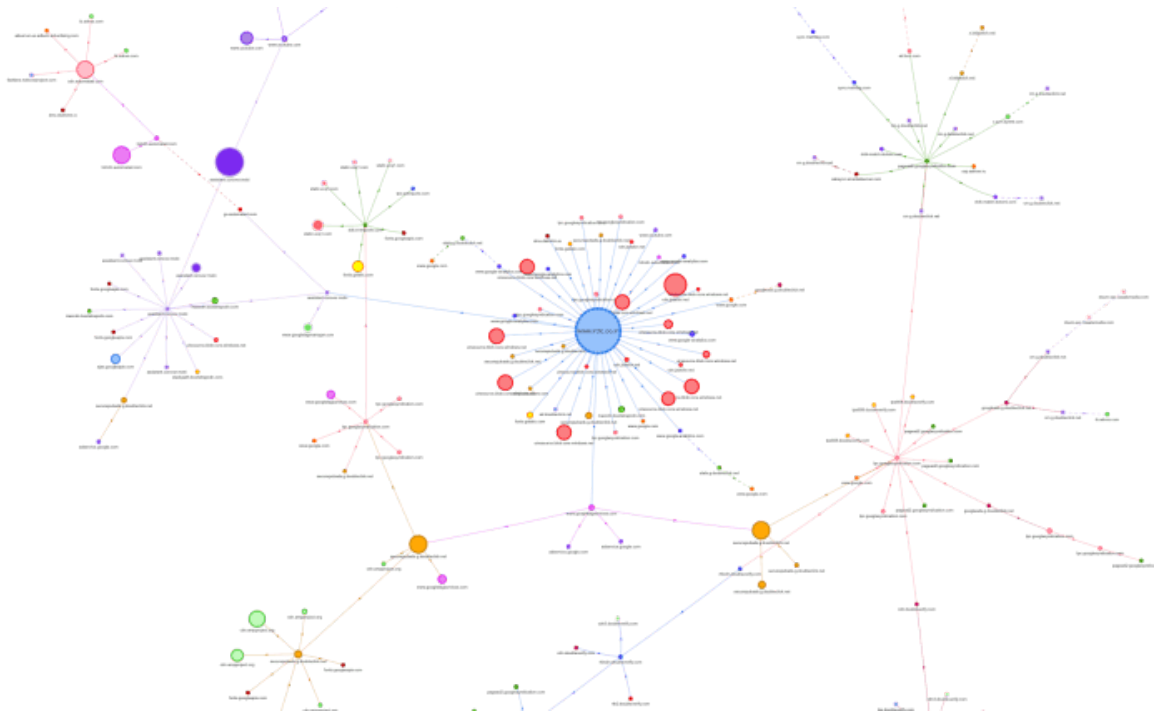


Request map for www.amazon.in

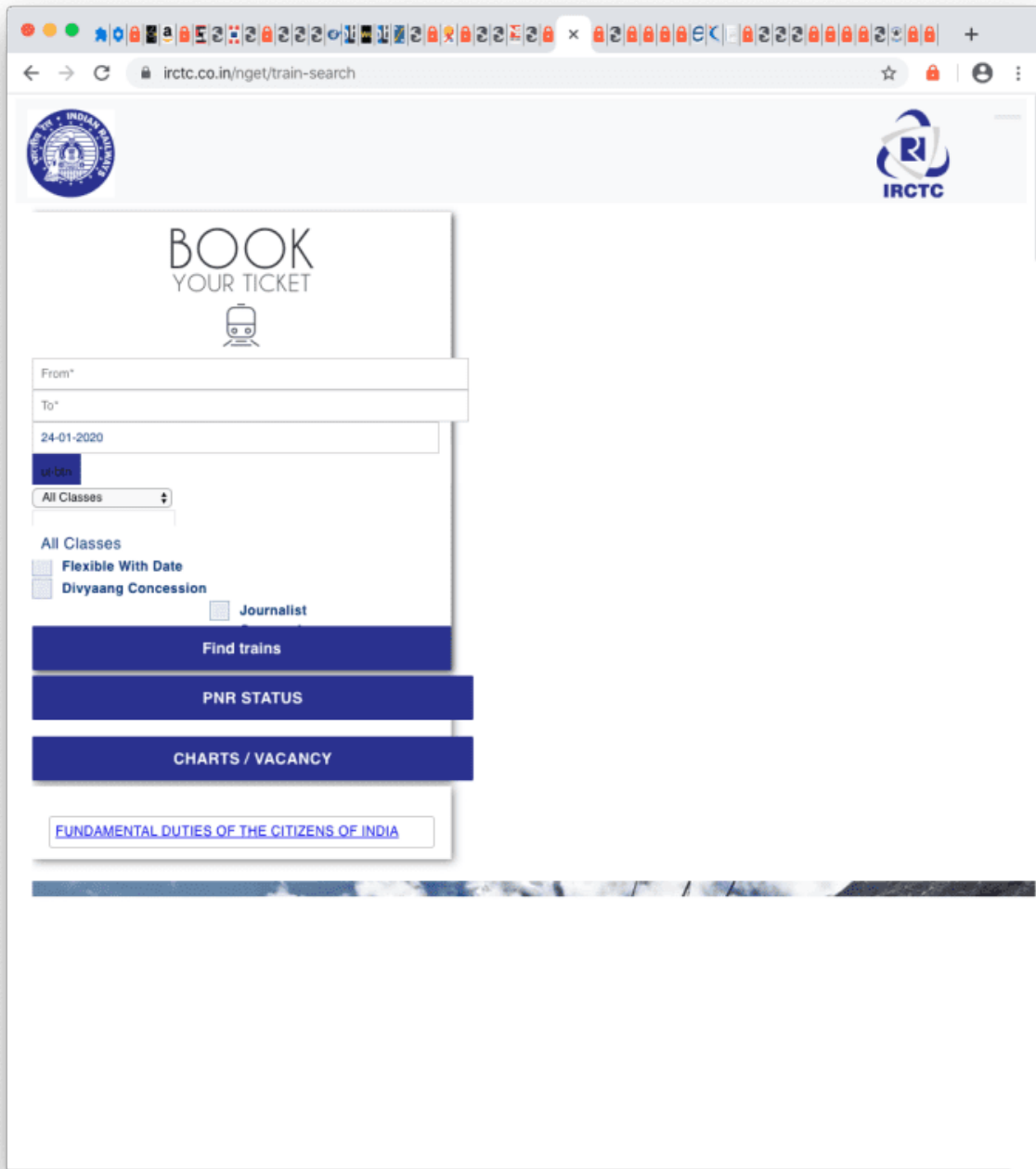


Screenshot of www.amazon.in

Example 2: In case of the website of the Indian Railways, www.irctc.co.in, once again, the [request map](#) indicates a large number of requests to other domains. This results in breaking the layout of the page (as is evident in the screenshot), as well as the operation of the website.



Request map for www.irctc.co.in



Screenshot of www.irctc.co.in

Example 3: The website of the Public Works Department of the Government of Jammu and Kashmir, www.jkpwdrb.nic.in, sends no requests to other domains as indicated by the [request map](#) and thus the whitelist restrictions have no visible impact. It should be noted that this kind of website setup is uncommon.



Request map for www.jkpwdrb.nic.in



Screenshot of www.jkpwdrb.nic.in

5. Search Engines

The updated list in the January 24 order contains 10 hostnames classified as search engines and www.bing.com classified under utilities.

1. The whitelist did not include Indian subdomains (google.co.in, in.search.yahoo.com) which means that users may not be able to access them, whether they type it manually or get redirected to the Indian domain of the search engine based on language or browser settings.
2. The list included Canadian and UK subdomains for Google. It also included the Canadian and French-Canadian versions of Yahoo Search. There was also no justification provided for the exclusion of Indian locales while including non-Indian locales.
3. We also found that while conducting a search was possible, a user could only successfully navigate to results from websites that were on the whitelist (subject to how they worked as determined by our testing). For websites not on the whitelist, the information contained in the snippets was readable on the search results page, but not beyond it.

So we have categorised search engines as 'partially usable'.

6. News/Technology Updates

The updated list in the January 24 order also contains 74 websites categorised as "news" (60) and "Technology Updates" (14).

1. There was a mix of regional, national and international websites.
2. Audio/podcast and video content for all of these sites was either delivered from subdomains/CDN domains or YouTube and hence did not work.
3. International publications such as The Washington Post, Wall Street Journal and The New York Times allow limited views before enforcing a paywall. However, their sign-in pages were not accessible. In such cases, even if the websites were minimally visually affected, they were categorised as 'practically not usable'.
4. For the remaining, we observed that the impact to page layout varied in degrees:
 1. All pages and UI elements were broken.
 2. Only Home page was broken.
 3. Only subsection pages were affected.
 4. Only article pages were not affected.

The categorisation between usable, partially usable and not usable was done on the basis of how easy or difficult it was to consume content and navigate within each website.

- **NDTV**
- BUSINESS
- हिन्दी
- MOVIES
- CRICKET
- LIFESTYLE
- HEALTH
- FOOD
- TECH
- **HO LIVE**
- AUTO
- SWASTH
- বাংলা
- தமிழ்
- APPS
- TRAINS
- ART

India News Today
Sections
[Home](#) | [Video](#)

[WATCH LIVE](#)

We, The Children Of India

PUBLISHED ON: January 25, 2020 | Duration: 50 min, 04 sec

loading..

Earlier this week, the National Commission for Protection of Child Rights (NCPCR) wrote to the district magistrate (DM) of south-east Delhi asking for an investigation into a complaint they received of children being "misled" at Shaheen Bagh about the Citizenship Amendment Act (CAA) by their elders and, as a result, may be suffering from 'mental trauma'. The top government child rights' body has now told the DM to send a child protection officer and a child welfare police officer to "identify these children and arrange counselling sessions for them and their parents, if deemed fit". They have 10 days to file a report. Meanwhile, three Congress-ruled states have made the Preamble to the Constitution part of school curriculum. The BJP has described the decision as a political one. They say it will backfire on Congress. We are asking tonight? Are India's children being made into pawns for politics? Should children be made aware of the politics of the day, given that they are going to inherit the world we leave them? Or should children be shielded from politics and be allowed to have a childhood?

Most Watched 

Screenshot indicating broken page layout

7. Additional Observations

1. **Mail:** The whitelist included 4 webmail services. However, none were usable since the sign-in pages required navigating to domains that were not on the whitelist. They have been categorised as ‘practically not usable’.
2. **Entertainment:** The updated list from the January 24 order also included 7 entertainment sites along with URLs which made testing them possible (this in contrast to the 6 listed in the January 18 order that did not include URLs and only named the services). Only one (<https://wynk.in>) of these was able to stream content successfully. It was categorised as ‘practically usable’ even though it may be difficult to stream content on a 2G network. 6 out of 7 have been categorised as ‘practically not usable’.. It should be noted that such content is typically consumed on apps which were not tested as a part of this exercise. Apps generally use different hostnames to request for resources.
3. **Official websites of apps:** The whitelist includes Gingerlabs.com, the official website for the note-taking mobile app Notability. Another entry, Kinemaster.com is the official website of the eponymous video-editing app for Android and iOS. The website enables users to get user support and interact with the community of users. For the purpose of this analysis, the websites were tested and categorised as per their usability. It should be noted that new downloads would not be possible since the Apple App Store and Google Play Store are not included in the whitelist. It is also unclear if users who already have these apps installed will be able to use them since the apps may not use the same domain(s) to make requests.
4. **URLs that contain paths:** Two URLs on the whitelist contain specific paths (www.marutisuzuki.com/MarutiSuzuki/Car and <https://www.heromotocorp.com/en-in/>). It is unclear how ISPs could whitelist these two entries without whitelisting the domains Marutisuzuki.com and Heromotocorp.com.

Summary of Findings

Number of entries in the whitelist	301	
Number of duplicate entries	13	
Number of invalid URLs	4	
Number of entries with no specified URL and no qualifying information about the website/service	8	

Number of inconclusive/indeterminate entries	6	
Number of URLs after validation and de-duplication	270	
Number of websites that are practically usable	58	Most of these websites are largely comprised of textual information.
Number of websites that are practically partially usable	68	Some important features are adversely affected.
Total number of websites usable to some degree	126	
Number of URLs in the list (no protocol or http) that default to https	94 out of 270	These may not work in actual use cases because of the redirect to https.

Usability by 'Field'	Practically Usable?			
	Could Not Test	No	Partially	Yes
Automobiles	1	1	1	1
Banking		8	7	
Education		25	14	7
Employment		1	1	1

Entertainment	7	8	1	2
Mail	1	3		
News	6	18	17	19
NGOs			1	4
Search Engines	1	4	5	
Services	4	5	1	3
Technology Updates		8	4	2
Travel	3	13	1	3
Utilities	8	49	15	15
Weather				1
Web Service		1	1	
Total	31	144	68	58

**The detailed results from testing all entries in the first version of the whitelist as recorded on January 22 and 23, IST are available [here](#). We updated the set of results on 26 January to reflect the next version of the whitelist, available [here](#). This version carries over all entries of the previous one unchanged.*

Method

Testing URLs on an Unrestricted Internet Connection

To test if all entries in the list were functioning, we first accessed them using an India IP address on an unrestricted 4G connection. The ones that were not functional were categorised as:

1. **Invalid URL:** 4 URLs are invalid. One (www.hajcommittee.gov.in) contains a typographical error. 3 others are badly formed (<https://www.google.com> > gmail; <https://oppo-in>; www.google.com > chrome [sic]).
2. **Duplicate URL:** 13 URLs were found to be duplicates of other entries. 3 URLs are present on the list along with their respective redirected versions. For instance, www.trivago.com redirects to <https://www.trivago.in>, both of which are present on the whitelist. We excluded the former from our analysis, and considered the redirected version. The other two instances are Airtel.in and Cleartrip.com.
3. **Entries with no URL specified:** We have excluded 8 entries that are names of services and not URLs. 7 of these are media services providers such as Netflix and Amazon Prime.
4. **Inconclusive entry/indeterminate URL:** 6 URLs returned an error message and were excluded. 3 of those — Gov.in, Nic.in and Ac.in — did not include a protocol (<http://> or <https://> or the www. prefix). The DNS registration for Gov.in and Nic.in had also expired as indicated by WHOIS at the time of writing this analysis.

The results have been logged and categorised according to this schema in the detailed analysis (available [here](#)):

<p>Is the URL accessible?</p>	<p>This column logs the results of a preliminary check for URLs that lead to error messages, such as broken links and websites/ webpages that are misconfigured.</p>	<p>The results are categorised as: Yes: The URL is accessible <i>Invalid URL; Duplicate URL; No URL specified; Inconclusive entry/ Indeterminate URL:</i> The URL or whitelist entry are not accessible for reasons described above.</p>
<p>Does the URL redirect to another?</p>	<p>The column indicates whether a URL redirects to another URL by default. Categorised as: Yes/ No</p>	

<p>Redirects to</p>	<p>This column specifies the redirect target URL, if it exists.</p>	<p>Categorised as: <i>No redirect</i></p> <p><i>https</i>: The initial URL on the whitelist either contains http or no protocol is specified. It redirects by default to its https version, with the rest of the URL being identical.</p> <p>Example, www.moneycontrol.com on the whitelist redirects by default to https://www.moneycontrol.com.</p> <p><URL>: The initial URL on the whitelist redirects by default to a URL with a different path or prefix. In such cases, the redirect target URL is specified here.</p> <p>Example, https://www.icicidirect.com redirects to https://www.icicidirect.com/indirectcontent/Home/Home.aspx</p>
<p>Remark/Observation</p>	<p>Observations based on the testing so far.</p>	

Whitelist Testing

The 270 URLs that remained were put through whitelist testing via a Chrome browser extension called [Whitelist Manager](#), via a 10 Mbps connection. This extension can be configured to restrict users from accessing any URLs except whitelisted ones.

The results have been logged and categorised according to this schema (available [here](#)):

Page Layout	This column logs how the page appears visually to the viewer. Classified as either Intact or Broken.	<ol style="list-style-type: none">1. <i>Intact</i>: The website was visually identical with and without the whitelist restriction in place.2. <i>Broken</i>: Its appearance was significantly altered when accessed with the whitelist restrictions.3. <i>Inaccessible due to redirects</i>: The website automatically redirected to another domain which was not on the whitelist. No further analysis was possible in such cases.
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Images loading?	Categorised as Yes/ No/ Partial.	<ol style="list-style-type: none">1. <i>Yes</i>: All Images appeared on the website even with the whitelist restrictions.2. <i>No</i>: No images appeared on the website with the whitelist restrictions.3. <i>Partial</i>: Some images on the website loaded with the restrictions.
Has sign-in?	This column logs whether the website provides its users with an option to sign-in for its services or for personalised content. Categorised as Yes/No.	

<p>Sign-in section visible?</p>	<p>This records if the sign-in page accessible or the sign-in section on the website is functional with the whitelist restrictions in place.</p>	<ol style="list-style-type: none"> 1. <i>Yes</i>: Sign-in page was under the whitelisted domain OR sign-in section of the website was responsive even if the page layout was broken 2. <i>No</i>: Sign-in required accessing a non-whitelisted domain OR sign-in section of the website was non-responsive. 3. <i>Partial</i>: The website also provided 3rd Party authentication options via Facebook/Google etc. which were not accessible. <p><i>Note</i>: The actual sign-in process was not tested for every website. There is potential for additional website failures if this relies on calls to non-whitelisted domains.</p>
<p>Other functions affected?</p>	<p>A subjective assessment of whether other parts of the website were impacted by the whitelisting restrictions. If any were found, these were listed in the 'Specify' column. This assessment should be considered indicative and not exhaustive.</p>	

<p>Practically usable?</p>	<p>A subjective assessment of whether the website could still be used or not.</p>	<ol style="list-style-type: none"> 1. <i>Yes</i>: Main features were not affected OR the website offered limited functionality to begin with that wasn't impacted. 2. <i>No</i>: Website is unusable as some key features are not functional OR visual elements were missing/ broken to such an extent that it could not be used in any meaningful way. 3. <i>Partial</i>: Some features (mainly textual information) were still functional.
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Limitations of Our Method

1. We tested the whitelisted entries for usability via a whitelist management extension for the Chrome browser. Results may differ if another whitelist management software were used on a different browser. However, the difference will not be large and significant enough to change our final assessment of whether the website was usable or not.
2. We conducted the tests on a 10 Mbps connection. We did not use the bandwidth throttling feature on Chrome since the primary intent was to determine whether the sites were accessible or not. In the actual use case, people will visit the whitelisted entries via 2G connections with which the websites that we were able to access may not be reachable in a reasonable amount of time.
3. We did not sign-in to any of the websites, try to write and send an email, carry out a financial transaction or upload a document such as a tax filing. Doing these activities may significantly alter the final assessment regarding their usability.
4. 94 URLs (http or no protocol specified) redirect by default on an unrestricted connection to their https version. We have thus tested the https versions only. This was done due to a limitation of the Chrome browser extension we used for the testing. (Refer to Column E entitled "Does the URL redirect to another?" in the spreadsheet containing detailed

analysis.) However, these 94 URLs may not function in the actual use case in Kashmir depending on the ISPs' implementation of the whitelist.

5. We focused on visual elements and usability only. We ignored the impact on analytics, monitoring tools as long as it did not impact the ability of an end-user to navigate the website. This is, however, bound to be a matter of concern for website operators.

Paper - II

This analysis was filed as part of an affidavit in the Supreme Court of India.

Implication of 4G and 2G connection speeds on web performance

Prateek Waghre

Abstract

The network speed available to a user i.e. 2G or 4G plays a highly significant role in determining how quickly/slowly they are able to complete their objectives or whether they are able to complete them at all. This document includes a theoretical comparison between 2G and 4G network speeds in the context of common tasks on the internet and a qualitative assessment of the effect that 2G can have on video streaming (broadcast) and video conferencing (interactive) applications. It also includes the results of a simulated performance comparison for selected use-cases to demonstrate the extent to which lower network speeds adversely impact the time taken by a person to successfully complete routine tasks over the internet.

4G v/s 2G speeds in India

As per TRAI ²,

“4G stands for the fourth generation of mobile connection speeds. 4G or LTE is upgraded mobile data technology that provides extremely high download data speed upto 150 Mbps and advanced LTE can provide download speeds upto 300 Mbps. Voice call service in LTE is provided over data/packet network (VoLTE- voice over LTE) unlike 2G/3G, where circuit switched network is used to make voice calls.”

And

“2G or GSM is a digital mobile technology that provides voice call service & data services with download speed upto 384 Kbps.”

The download speeds listed above are theoretical values. In practice, the speed available to users will be a function of network coverage/deployment, congestion and allocation/availability

² TRAI Myspeed portal - FAQ ; <https://myspeed.trai.gov.in/faq.php>

of spectrum. Based on reports from Ookla³ and OpenSignal⁴, which measure samples from across India, a representative set of 4G parameters can be estimated for analysis⁵.

2G speeds and latency are no longer specifically measured by either Ookla or OpenSignal. The latter, in a report dated April 2017⁶ stated:

“(We exclude 2G as 2G results vary little from operator to operator and generally don’t provide enough bandwidth for an adequate mobile data experience)”

TRAI also explicitly filters out 2G log lines as mentioned in its Whitepaper on Measurement of Wireless Data Speeds⁷. Joint-research conducted by CUTS and IIT Delhi⁸ provides parameters which can be used as representative values for analysis⁹. It is also worth noting that Ookla has published an analysis indicating a slight downward trend in network speeds due to COVID-19¹⁰.

The following can be considered to be representative¹¹:

4G

- Download Speed : 9.8 Mbps
- Upload Speed : 2.9 Mbps
- Latency : 60 ms

Hereafter referred to as Observed 4G Download Speed / Upload Speed / Latency

2G

- Download Speed : 168 kbps
- Upload Speed : 100 kbps
- Latency : 310 ms

Hereafter referred to as Observed 2G Download Speed / Upload Speed / Latency. The theoretical speed of 384 kbps is hereafter referred to as Peak Theoretical 2G Download Speed.

³ Ookla India Data : <https://www.speedtest.net/global-index/india>

⁴ India Mobile Network Experience, April 2020 :
<https://www.opensignal.com/reports/2020/04/india/mobile-network-experience>

⁵ While these parameters will vary across the country, the listed values can be considered to broadly representative

⁶ State of Mobile Networks - India (April, 2017) :
<https://www.opensignal.com/sites/opensignal-com/files/data/reports/national/data-2017-04-india/report.pdf>

⁷ Page, 25 : https://myspeed.trai.gov.in/WhitePaper_measurement_wireless_data_speed.pdf

⁸ CUTS (2016), IIT Delhi, Mobile Internet Services in India: Quality of Service, CUTS, Jaipur :
http://www.iitd.ac.in/research/IITD/1615_QoS_Report_CUTS_IIT.pdf

⁹ Refer to 4

¹⁰ Speedtest, Tracking COVID-19’s Impact on Global Internet Performance
<https://www.speedtest.net/insights/blog/tracking-covid-19-impact-global-internet-performance/>

¹¹ Refer to 4

State of the Web

httparchive's State of the Web report has analysed nearly 10 million URLs and published the following observations regarding Desktop and Mobile URLs as of March 1 2020 ¹².

Table 1 includes 75th percentiles ; i.e. 75% of measurements will fall within the values listed. 25% or 1 of every 4 samples will have corresponding values higher than those represented in the table.

Definition of parameters listed (as per httparchive reports):

- Total Kilobytes : *The sum of transfer size kilobytes of all resources requested by the page.*
- Total Requests : *The number of resources requested by the page.*
- Image Bytes : *The sum of transfer size kilobytes of all external images requested by the page.*
- Image Requests : *The number of external images requested by the page.*
- DOMContentLoaded : *The number of seconds from the time the navigation started until the initial HTML document has been completely loaded and parsed, without waiting for the stylesheets, images and subframes to finish loaded.
Typically, a number of elements on the page are visible by this point however the page may or may not be usable. That is dependent on page design and browser rendering*
- onLoad : *The number of seconds from the time the navigation started until the document and all of its dependent resources (images, stylesheets etc) have finished loading.
Note that a page typically becomes usable/interactive (Time to Interactive) some time in between DOMContentLoaded and OnLoad events. Time to Interactive implies that some of the functionality on a page is now available - it is a non-standardized web performance metric. It does not mean that a page is fully functional, that can vary based on website design and browser performance.*

¹² httparchive, State of the Web,
https://httparchive.org/reports/state-of-the-web?start=2019_08_01&end=latest&view=list

Table 1: Page parameters derived from httparchive State of the Web report.

Parameter (Percentile)	Mobile	Desktop
Total Kilobytes (p75)	3624.7	3987.7
Total Requests (p75)	114	120
Image bytes (p75)	2362.1 Kilobytes	2529 Kilobytes
Image Requests (p75)	48	53
DOMContentLoaded (p75)	7.4 seconds	2.9 seconds
onLoad (p75)	30.9 seconds	10.7 seconds

Based on Total Kilobytes in Table 1 and observed 4G and 2G (+ peak theoretical 2G) download speeds, it is possible to estimate the expected time to download a page and its resources.¹³

Table 2 : Theoretical comparison of page download times from Table 1.

4G (Observed Download Speed)	2G (Observed Download Speed)	2G (Peak Theoretical Download Speed)
Mobile ¹⁴ : 2.96s	Mobile ¹⁵ : 2 mins 52s	Mobile : 1 min 15.5s
Desktop ¹⁶ : 3.25s	Desktop ¹⁷ : 2 min 59s	Desktop : 1 min 23s

¹³ Refer to 16.

¹⁴ 3624.7 KiloBytes (KB) = 28,997.6 Kilobits (Kb) (1 Byte = 8 bits). 28,997.6 Kb / 9.8 * 1000 Kbps = 2.95 seconds.

¹⁵ 3624.7 KiloBytes (KB) = 28,997.6 Kilobits (Kb) (1 Byte = 8 bits). 28,997.6 Kb / 168 kbps = 172.6 seconds.

¹⁶ If using a hotspot; From 12 Replace 3624.7 with 3987.7

¹⁷ If using a hotspot; From 13 Replace 3624.7 with 3987.7

Table 3 : Theoretical comparison of image download times from Table 1.

4G (Observed Download Speed)	2G (Observed Download Speed)	2G (Peak Theoretical Download Speed)
Mobile : 1.93s	Mobile : 1 min 53s	Mobile : 49.21s
Desktop : 2.06s	Desktop : 2 mins	Desktop : 52.69s

Table 4: Theoretical comparison of download times for a 5 MB file.

4G (Observed Download Speed)	2G (Observed Download Speed)	2G (Peak Theoretical Download Speed)
4.08s	3 mins 58s	1 min 54s

Inference(s) :

1. At Observed 2G download speeds, the same task **could take upto 50x longer** than at Observed 4G download speeds.¹⁸
2. At Peak Theoretical 2G download speeds, the same task **could take upto 25x longer** than at Observed 4G download speeds.¹⁹
3. As a security best-practice, OWASP recommends²⁰ setting the server timeout to the minimal possible value based on the context of the application. In addition, intermediaries and clients impose timeouts on connections too. There is no universal value for these settings. **The higher the time required to download content, the greater is the likelihood of such timeouts being encountered.**

¹⁸ This is meant to be indicative. It does not take into account the time taken for multiple requests to traverse back and forth over the internet and any processing time at the origin server. As 4G latency is 1/6th of 2G latency, the high ratios will hold even when that is taken into account.

¹⁹ Refer to 16.

²⁰ OWASP (Open Web Application Security Project) Community , https://owasp.org/www-community/Session_Timeout

Audio / Video Streaming and Delivery

At a high-level, Audio-Video content delivered over the internet can be divided into 2 categories

1. Audio / Video Streaming (Broadcast)

General purpose video content such as those available on platforms like YouTube, On-Demand e-learning content, Netflix, HotStar, Live streaming of news content, speeches made by the Prime Minister, etc. all fall under this category. Today, such content is most commonly delivered via protocols like Apple's HLS (HTTP Live Streaming) and MPEG-DASH (Motion Picture Experts Group - Dynamic Adaptive Streaming over HTTP). These protocols enable ABR (adaptive bitrate streaming) which is the ability for the video quality to be changed in accordance with the bandwidth available at a user's device.

It can also be delivered as a progressive media download or a single file download.

The QoS (Quality of Service) metrics typically used are startup time²¹, lag or re-buffer ratio²² and frame loss²³. These metrics require advanced analytics so a quantitative analysis of video performance on 2G v/s 4G cannot be made in the same way as the previous (and following) section.

Some qualitative inferences can be derived based on the system requirements published by Youtube²⁴ and Netflix²⁵. These companies have been selected as examples because they are consistently at the fore-front of streaming technology and video delivery at scale, and not for the nature of content they may or may not provide.

A) Youtube

Video Resolution	Recommended sustained speed
4K	20 Mbps
HD 1080p	5 Mbps
HD 720p	2.5 Mbps
SD 480p	1.1 Mbps

²¹ Time taken for playback to start, also known as buffer fill.

²² Ratio of time spent waiting for video playback to time spent watching the video.

²³ Video frames dropped.

²⁴ System Requirements, <https://support.google.com/youtube/answer/78358?hl=en>

²⁵ Internet Connection Speed Recommendations, <https://help.netflix.com/en/node/306>

SD 360p

0.7 Mbps

B) Netflix

... internet download speed recommendations per stream for playing TV shows and movies through Netflix.

- *0.5 Megabits per second - Required broadband connection speed*
- *1.5 Megabits per second - Recommended broadband connection speed*
- *3.0 Megabits per second - Recommended for SD quality*
- *5.0 Megabits per second - Recommended for HD quality*
- *25 Megabits per second - Recommended for Ultra HD quality*

Inference

- It should be noted that even the lowest recommended settings are higher than both the Observed 2G speed and Theoretical Peak 2G speed. Thus video viewing experience will be **subject to significant degradation compared to 4G speeds**.

2. Audio / Video Conferencing (Interactive)

Video Conferencing services like Zoom, Cisco Webex, Skype, Interactive elearning classes, VOIP, WebRTC etc. would fall in this category.

In such applications, in addition to the bandwidth or speed, network latency, jitter and packet loss are important QoS metrics.

Zoom lists the following bandwidth requirements for mobile devices ²⁶

The bandwidth used by Zoom will be optimized for the best experience based on the participants' network. It will automatically adjust for 3G or WiFi

Recommended bandwidth over WiFi:

- *For 1:1 video calling: 600kbps (up/down) for high quality video and 1.2 Mbps (up/down) for HD video*
- *For group video calling: 600kbps/1.2Mbps (up/down) for high quality video. For gallery view: 1.5Mbps/1.5Mbps (up/down).*

Skype recommends (download/upload):

- For 1:1 High Quality calling : 500 kbps / 500 kbps
- For 1:1 HD Quality calling : 1.5 Mbps / 1.5 Mbps

²⁶ Zoom - System Requirements, <https://support.zoom.us/hc/en-us/articles/201179966-System-Requirements-for-iOS-iPadOS-and-Android>

- Group (3 people) : 2 Mbps / 512 Kbps
- Group (7+ people) : 8 Mbps / 512 Kbps

Facebook / Whatsapp have not published bandwidth recommendations for VOIP and Video calls.

For the other parameters, acceptable values are ²⁷

- Latency : < 150 ms
- Jitter : 10-50 ms
- Packet Loss : 0.5-1%

Currently, no representative values for Jitter and Packet Loss are available for 2G in India.

Inference

- Comparing the **available recommendations** for bandwidth and latency with Observed 2G speed and latency indicates that **users will face significant issues when using video conferencing applications**. These **issues will be exacerbated by multitasking**, as expected in the current scenario.

²⁷ Cisco, Transport network SLAs,
<https://www.cisco.com/c/en/us/support/docs/quality-of-service-qos/qos-video/212134-Video-Quality-of-Ser-vice-QOS-Tutorial.html#anc11>

Simulated Comparison between 2G and 4G

Objective:

In order to estimate how the difference in Observed 2G speed and Observed 4G speed may translate into practice, simulated tests were run for a few selected use-cases. ²⁸

Testing Methodology

In order to simulate the Observed 2G and 4G network speeds the following methods were used:

1) Charles Proxy²⁹

Charles is an HTTP Proxy that makes it possible to view all HTTP and in some cases HTTPS requests between a machine and the internet. It also has a 'Throttle' setting that was programmed with the Observed 2G and 4G speeds. Requests were made through an iPhone 5s which was proxied through Charles to enforce the speed conditions. This method was used for use-case 1.

2) Chrome Developer Tools

Google Chrome's built-in Developer Tools also provide the ability to simulate a mobile device and network conditions. These were programmed with the Observed 2G and 4G speeds. This method was used for use-cases 2-7.

Note :

- While these methods can simulate the speed restrictions accurately, they may not reproduce the consequences of network congestion, packet loss, low signal strength that end-users may encounter in practice. These issues will affect 2G performance to a larger extent than they would impact 4G performance.
- The tests were run multiple times to weed out any outliers. Representative results have been used.

²⁸ 2G network at the author's location could not even run a standard speedtest while 4G network indicated a speed of 21 Mbps, thus would not represent a meaningful comparison. Therefore observed 2G and 4G network speeds from the previous section were used.

²⁹ Charles - <https://www.charlesproxy.com>

Test Cases

Table 5: Comparison of time taken on 2G v/s 4G

Sl. No.	A. Test Case	B. Time taken on Observed 4G speeds	C. Comments	D. Time taken on Observed 2G speeds (in multiples of B)
1.	Download Arogya Setu App (23.6 MB)	2 min 25s		11x
2.	Sample 12 MB File ³⁰	24s		24x
3.	Access MOHFW website ³¹	1s (DCL) * 2.9s (PL) **		24x (DOM) 20x (PL)
4	Sample PDF from MOHFW Website (5.8 MB) ³²	5s		54x
5	WHO International website ³³	4s (DCL) 8s (PL)		27x (DOM) 22.5x (PL)
6	WHO Situation Dashboard ³⁴	1.58 (DCL) 1.6 (PL)	<i>Dashboard did not load visually on 2G</i>	NA - Dashboard did not work on 2G
7	COVID-19 Awareness Image on Twitter ³⁵	1.5s		37x
8	Vedantu - Home Page ³⁶	2.2s (DCL) 4s (PL)		16x (DCL) 31.5x (PL)
9	Upload 12 MB File (WeTransfer)	37s		26x
10	JK Motor Vehicles Dept	12.5s (DCL) 13s (PL)		21x (DCL) 19x (PL)
11	Youtube Home Page	1s (DCL)		26x (DCL)

³⁰ https://eoimages.gsfc.nasa.gov/images/imagerecords/49000/49958/pacific_goe_2011079_lrg.jpg

³¹ <https://mohfwa.gov.in>

³² <https://www.mohfw.gov.in/pdf/NBTCTGUIDANCEFORCOVID19.pdf>

³³ <https://who.int>

³⁴ <https://who.sprinkl.com/>

³⁵ <https://pbs.twimg.com/media/ESWEFtFU4AENWAX?format=jpg&name=4096x4096>

³⁶ <https://www.vedantu.com/>

		1.8s (PL)		25x (PL)
12	Youtube Sample Video Playback 1 ³⁷	1s (DCL) 2.2s (PL) Video Start 1s -near instant Playback at 480p: No buffering Playback at 360p: No buffering		35x (DCL) 21x (PL) Video start 60x Playback at 480p: Significant buffering. <i>For every 1s of playback, there were 1.2s of buffering.</i> Playback at 360p: Significant buffering. <i>For every 1s of playback, there were 0.7s of buffering.</i>
13	Youtube Sample Video Playback 2 ³⁸ (Action scene)	1s (DCL) 2.6 (PL) Video Start 1s - near instant Playback at 480p: No buffering Playback at 360p: No buffering		26.5x (DCL) 17x (PL) Video start 52x Playback at 480p : Extremely significant buffering. <i>For every 1s of playback there were 3.8s of buffering..</i> Playback at 360p: Very significant buffering. <i>For every 1s of playback there were 2.3s of buffering.</i>
14	10-12s Video upload on Whatsapp	43s		27x

* DCL - DOMContentLoaded event

** PL - PageLoad or OnLoad event

³⁷ <https://youtu.be/IJoXu0k4fIU> (MHOFW Awareness Video)

³⁸ <https://m.youtube.com/watch?v=GSrtUVzdt6M>

Observation(s)

- Tasks on **Observed 2G speeds took 11 - 37 times longer than they did on Observed 4G** speeds in the simulated environment. This ratio may increase in real world scenarios once congestion, packet-loss, signal strength etc are accounted for.
- Some **interactive interfaces** like WHO's Situation Tracker **did not function at Observed 2G speeds**.
- Video playback on Observed 2G speeds faced significant degradation compared with Observed 4G speeds. **Playback was near instant at Observed 4G speeds but took upto 60x longer on Observed 2G speeds**. There was also significant buffering at Observed 2G speeds, depending on the nature of video (high-action v/s low-action) and resolution playback was constantly interrupted by buffering. **For every 1s of video watched there was 0.7 to 3.8s buffering. i.e. a 20 minute video could end up taking anywhere from 34 minutes to 1 hour 36 minutes to watch completely.**