Defeating the Digital Divide: Internet Costs, Needs, and Optimal Planning

Executive Summary:

The Internet and the access to it have become one of the twenty-first century's most important utilities. Studies have shown that the internet is more than just a luxury- it's an essential- it can determine whether a family is up to date on current events, has access to critical information on medicine plus access to it, be the underlying issue of performing or finding employment, and ensure whether or not a child's education is behind a paywall. The importance is undeniable and that's why accessing and providing it to economically disadvantaged communities is a priority; however, the method in which we provide it is under debate: broadband, fiber optic, satellites or mobile. All are great and if implemented will improve communities. In our model we determine the average cost of bandwidth for consumers in The United States or United Kingdom during the next ten years.

Later on we also aim to solve the cost of broadband a family might need given different scenarios. Every person's scenario is different, some require more and others can survive with less. Using this we also determine how much minimum broadband required for each scenario as well as what percentile meets ninety percent and ninety nine percent of bandwidth needed.

Nodes are the essential key component towards wireless cellular data transformation. Pinpointing the number of nodes in a specific regent is valuable information to optimally expand or cover a community's access to the internet and bandwidth access. Determining an equation to predict the location that best serves the community saves money to provide countless benefits to the recipient and their family.

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1. The Cost of Connectivity

1.1 Restating

Bandwidth is the measurement of the download speed of a person's internet connection. The Federal Communication Commission defines Broadband as speeds above 25mbps. In the United States, the average download speed is 143.28Mbps, while the United Kingdom has average download speeds of 67.78Mbps [1].

1.2 - Assumptions

Assumption 1: Starting In 2020 And Ending 2030

Justification: 2021 is not yet complete therefore the data for this year is not fully complete

Assumption 2: US $0.43 Price per MB (avg 143.28 Mbps), in 2020 || UK $0.60 Price per MB, in 2020 (avg 67.78 Mbps)

Assumption 3: The average rate of change for the price of a megabit from 2016 and 2020 is -0.115% for the US average rate of change for the price of a megabit from 2016 and 2020 is 9.72% for the UK.

Justification: US $0.89 Price per MB, in 2016 and UK $.34 Price per MB, 2017 28.9 mbps 2016 UK [1]

1.3 - Variables Used

Symbol	Definition	Unit	Value
P_n	Price of the Current Year	$/mbps	...
P_1	Price of the Starting Year	$/mbps	US $0.43 UK $0.60
n	Current Year	...	...
r	Common Ratio	...	US 0.9885 UK 1.0972

1.4 - Creating the Model

In order to predict the cost of the Mbps in the coming decade we used a geometric sequence.

$$P_n = P_1 r^{n-1}$$

With this we can find the next term in the series all the way up to P_{11} which will be year 2030. We utilized the values for 2020 as our starting point in order to account for the fact that 2021 values are incomplete.

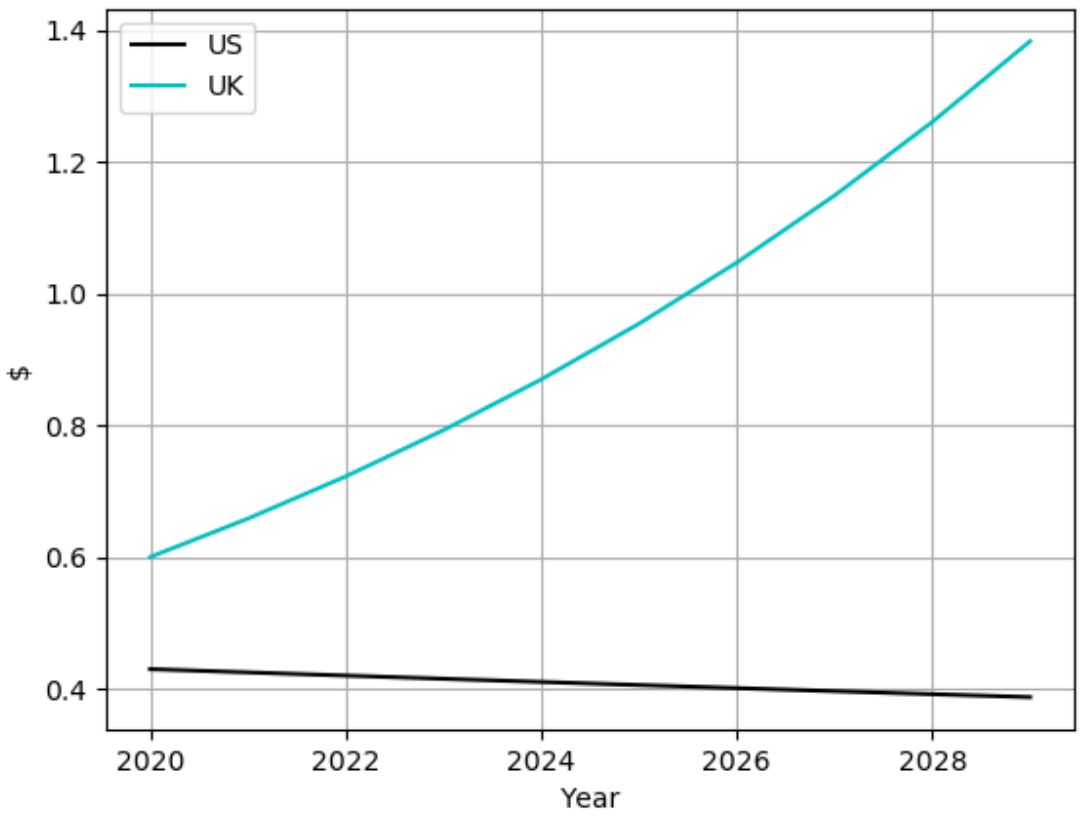
We found that the United States had an overall Dollar per Mbps of $0.43 [1] and a rate of change of -0.115% each year. When put into terms of common ratio we find that we can set its value at 0.9885. We found that the United Kingdom had an overall Dollar per Mbps of $0.60 [1] and a common ratio of 1.0972.

1.5 - Using The Model

By inputting the parameters we agreed upon we were able to create a table listing all price value predictions in the next decade.

Year	US Dollar per Mbps	UK Dollar per Mbps
2020	$0.43	$0.60
2021	$0.425055	$0.6583
2022	$0.420166	$0.7223
2023	$0.415334	$0.7925
2024	$0.410558	$0.8695
2025	$0.405837	$0.9541
2026	$0.401170	$1.047
2027	$0.396556	$1.149
2028	$0.391996	$1.26
2029	$0.387488	$1.383
2030	$0.383032	$1.517

Table 1: Price predictions in the US and the UK over the next decade



Graph 1: Showcases in visual form the trends of broadband price

When graphed these predictions show that the price of broadband following current trends will rise in the United Kingdom but lower In the United States.

2. Bit by Bit

2.1 Restating

Internet Usage is highly dependent on the person, his occupation, hobbies, and preference in entertainment, all factor into how much a person actually needs versus how much they want. We measured how much bandwidth a mid thirty year old couple might need with a three-year old child. A retired elderly woman taking care of two students twice a week. And three (M-3) full time College Students dorming together completing their college education while also working part time.

We used the data provided to us [6] to find the minimum bandwidth for a year in the case of 3 groups. It was very simple to find what information we needed since we were determining it by ages. Then, with the activities done by certain people by age group, we would find out how much bandwidth they use with [5]. Lastly, we would multiply our value by 52 (weeks), 90%, and 99% since we are finding minimum bandwidth.

2.2 Resources Used [6]

1st Quarter of 2019	**Age Category**					
Activity	**2-11**	**12-17**	**18-34**	**35-49**	**50-64**	**65+**
Watching Traditional Television	13.65	8.77	13.40	26.07	40.83	**50.80**
TV Connected Game Console	2.92	4.08	3.73	1.62	0.45	**0.15**
TV Connected Internet Device**	5.55	3.43	5.33	4.95	3.40	**2.17**
Internet on a Computer (not including video)	--	--	3.70	4.25	4.40	**2.77**
Video on a Computer	--	--	0.87	0.63	0.50	**0.23**
Total App/Web on a Smartphone	--	--	24.67	25.02	19.53	**13.37**
Video Focused App/Web on a Smartphone	--	--	2.50	1.62	0.98	**0.58**
Streaming Audio on a Smartphone	--	--	0.70	0.57	0.37	**0.20**
Total App/Web on a Tablet	--	--	4.37	6.03	6.12	**7.12**
Video Focused App/Web on a Smartphone	--	--	1.05	0.92	0.58	**0.60**

Streaming Audio on a Smartphone	--	--	0.10	0.15	0.10	**0.08**

Table 2: Amount of hours per week on each specific activity (First Quarter of 2019)

Italicized: web browsing(adults) = 31.92 x 1mb minimum required = 31.92mb / week

Bold: SD video streaming(adults) = 7 x 3mb minimum required = 21 mb / week

70 year old - 0.15+2.17+2.77+13.37+7.12+*0.69*+*1.74*+0.20+*1.8*+0.08 = 31.92

3rd Quarter 2015	**Income Category**			
Activity	**< $25K**	**$25k-50K**	**$50k-75K**	**> $75K**
Watching Traditional Television	49.29	40.23	33.72	26.53
TV Connected Game Console	9.89	7.83	5.34	4.19
TV Connected Internet Device**	9.14	7.94	6.21	4.30
Total Internet on a Computer	12.01	9.71	9.12	7.85
Total App/Web on a Smartphone	13.14	12.05	12.05	10.43
Total App/Web on a Tablet	6.84	7.12	6.97	6.42
Percent of Households in Income Category	**17**	**25**	**21**	**37**

Table 3: Income relating to the amount of time doing each specific activity (3rd Quarter of 2015)

Activity	**Required Bandwidth**
Online gaming	1-3 Mbps
Video conferencing	1-4 Mbps
Standard definition video streaming	3-4 Mbps
High definition video streaming	5-8 Mbps
Minimum *required* speed for Netflix video	.5 Mbps

streaming.	
Minimum speed for SD streaming with YouTube.	.7 Mbps
Minimum speed for HD streaming on YouTube.	2.5 Mbps
Netflix *recommendation* for SD video streaming.	3.0 Mbps
Netflix *recommendation* for HD video streaming.	5.0 Mbps
Netflix *recommendation* for Ultra HD (4K) video streaming.	25 Mbps
General web surfing, email, social media	1 Mbps

Table 4: Amount of Megabytes per second for each specific activity

2.3 Scenarios

Q1. A couple in their early 30's (one is looking for work and the other is a teacher) with a 3-year-old child.

Look for the information we need in the spreadsheet

D4 look at age data 2-11(for 1 person) & 18-34 (for 2 people)

Assumption: The child can only watch TV, TV Connected Game Console, TV Connected Internet Device while adults can do everything else.

Justification- Spreadsheet (D4) shows what each age group does respectively.

Assumption: The year is 2020-2021

Assumption: Both adults watch use TV Connected Game Console, use TV Connected Internet Device, use Internet on a Computer (not including video), use Video on a Computer, use Total App/Web on a Smartphone, use Video Focused App/Web on a Smartphone, Stream Audio on a Smartphone, use Total App/Web on a Tablet, use Video Focused App/Web on a Smartphone, and Steam Audio on a Smartphone.

Assumption: Families are located in the United States

Assumption: Unemployed adults stay unemployed for the whole year.

Assumption: Covid-19 does not exist.

Justification - since data in D4 only shows Q1 for 2020, there is not enough information to account for COVID-19, therefore it is normal data.

Assumption: All video streaming is standard definition.

52.92 x 2 adults = 105.84 x 52 weeks = 5,503.68 total mb in a year for 2 adults

2.92+5.55= 8.47 x 52 weeks = 440.44mb per year

5,503.6+440.44= 5,944.04 mb per year whole family

90% = 5,349.64 mb And 99% = 5,884.60 mb For Minimum required bandwidth

Full year of bandwidth	**90% bandwidth**	**99% bandwidth**
5,944.04 mbps	5,349.64 mbps	5,884.60 mbps

Table 5: Prediction of minimum amount of data used for a couple and their child

The Amount of Bandwidth Needed for a young thirty's teacher, with a three year old baby, and a husband constantly looking for employment needs at minimum 5,944.04mbps for a year. Ninety percent of her needs would be 5,349.64mbps and Ninety Nine Percent of the required bandwidth to cover her needs would be 5,884.6.

Q2. A retired woman in her 70's who cares for two school-aged grandchildren twice a week.

Assumption: Families are located in the United States

Assumption: The grandmother watches traditional TV

Assumption: The two grandchildren attend online school and have plus use smart devices

Assumption: Children come afterschool

Retired Women Minimum Usage: 30.09 mbps per day

0.15+2.17+2.77+13.37+7.12 = 25.58 (Web Usage) * 1Mbps (Requirement for General Usage) + *0.69*+*1.74*+0.20+*1.8*+0.08 = 5.51 (Video+Audio Streaming) = 30.09 mbps 1 week (Total)

30.09 * 52 = 1564.68 mbps

14.857 weeks approximately at grandma's house

2 School Children:

2* [16.65 (tv connected internet device) + 5.84 (Video games) * 14.857 (Weeks approximately per year)] = **668.268 mbps**

1564.68+668.268= 2232.95 mbps per year for the whole family

Full year of bandwidth	**90% bandwidth**	**99% bandwidth**
2,232.95 mbps	2,009.66 mbps	2,210.621 mbps

Table 6: Prediction of minimum amount of data for grandmother and two school age grandchildren

The grandmother spends a majority of the time watching TV so it doesn't take a lot of bandwidth to begin with, along with the kids only coming twice a week. They have the lowest bandwidth usage out of all scenarios.

Q3. Three former M3 Challenge participants sharing an off-campus apartment while they complete their undergraduate degrees full-time and work part-time.

Assumption: They live in and receive their education in United States

Assumption: Are 18 to 21 years old

Assumption: Make less than 50k combined

Justification: Most full time College students who work part time make around thirteen thousand a year [4]

Assumption: College Classes are In Person

Using Math From Q1 since the age range is the same, the only difference is we add an extra adult to equate to 3.

8,255.52 total bandwidth a year

Full year of bandwidth	**90%**	**99%**
8,255.52 mbps	7,429.97	8,172.97

Table 7: Prediction of minimum amount of data used three undergraduate students

Since the college students draw parallel to the first scenario in Q1 based on age range from 18-34 we could mimic the amount of bandwidth needed and adjust for college students who happen to work as well. Multiplying with the average usage for a 18 to 34 year old by three gives us a year's worth of 8,255.53mbs. working part time jobs. The 90% being 7,429.97 and 99% being 8,172.97. We found out that the college students used the most bandwidth. It makes sense considering how much time college students need on the internet for their online classes.

3. Mobilizing Mobile

3.1 - Variables Used

Symbol	Definition	Unit	Value
p(a)	population average Mbps consumption	Mbps	...
N(a)	Node average release	mbps	...
F(a)	Frequently average	MHz	...
D(a)	average download speed	Mbps	...
R(a)	Average range of 1 node	miles	...

3.2 - Assumptions

Assumption: Assume that the age of the population of the region follows the data of the age category of the first quarter of 2019.
Assumption: 908,525 is the amount of mbps the whole population of region B needs to use in 3 months, so in 1 year the whole population of region B would need 3,634,100 mbps.
Assumption: since 33.64 square miles is the area of region B. 33.64 square miles can be converted to 5.8 miles in region B
Assumption : (Average download speed *frequency)/average range of single node = Mbps Per Node

3.3 - Developing Model

We used the table provided for a previous question in order to find the quantity of Mbps that the population of an entire region will use.

1st Quarter of 2019	**Age Category**					
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Age	**Total percentage of the population**	**≈ Age category Mbps data**	**Total Mbps used by the Population (3 months)**	**Number of people in relation to the population**	**Total amount of mbps used per person**
9 and Under	5.21+5.03= 10.24%	2-11	34,098.6	1,514	22.12
10-19	12.73%	12-17	31,192	1,916	16.28
20-34	14.52%	18-34	132,017	2,185	60.42
35-54	22.92%	35-49	247,813.5	3,450	71.83
55-64	14.88%	50-64	173,062	2,240	77.26
65-85 and over	24.71%	65+	290,342	3,719	78.07
Total	100%	...	908,524.5	15,024	...

We added the values for each category together in order to find a rough match for the data in the table on page 12. E.g adding Region B's age 5-9 category and less than 5 category and roughly matching it with the age category 2-11, 5.21+5.03=10.24%.

bandwidth	Average download speed(Mbps)	Average range of a single node (Miles)	Average frequency (MHz)	Mbps Per Node in Region B
Low	**155**	**15**	**950**	**9,816.7**
Mid	**550**	**2.5**	**4250**	**935,000**
High	**2,500**	**.75**	**43500**	**81,562,500**

3.4 Model

Population consumption in 1 year/ 1 node's mbps release in 1 year = number of nodes needed for the population of the region.

This model can be used for both region A, and C, and for any region given a sufficient amount of data about their download speed, frequency, a range of a node

P(a) /N(a)=#N

Low= 3,634,100/9,816.7=370 low bandwidth nodes needed for region B to support 1 year

Mid= 3,634,100/935000=3.8 mid bandwidth nodes needed for region B to support 1 year(4 is sufficient)

High= 3,634,100/81562500= .0445 high bandwidth nodes needed to support region B in 1 year(1 is sufficient)

References

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[2] Jackson, Mark. "Ofcom 2016 Report - Average UK Home Broadband Speeds Reach 28.9Mbps." *ISPreview UK*, 25 Mar. 2016, www.ispreview.co.uk/index.php/2016/03/ofcom-2016-report-average-uk-home-broadband-speeds-reach-28-9mbps.html#:~:text=The%20telecoms%20regulator%20has%20today,year%20to%2028.9Mbps%20now.

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[4] "Understanding College Affordability." *Understanding College Affordability - Urban Institute*, collegeaffordability.urban.org/covering-expenses/working-during-college/#/who_works__and_how_much_.

[5] NerdWallet. "How to Decide What Internet Speed You Need." *NerdWallet*, 20 Feb. 2021, www.nerdwallet.com/article/finance/how-to-decide-what-internet-speed-you-need.

[6]m3challenge.siam.org/sites/default/files/uploads/breakdown/TCP_2021_data_FINAL.xlsx.