M3C Paper Team 15160

Suyoag Patwardhan, Arihant Bapna, Mwila Bweupe,
Stevie Miller, Kobe Wang

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1 Executive Summary

The COVID-19 Pandemic has highlighted the need for stable internet. The increased importance on digital connections has amplified fears of a "digital divide", in which lack of reliable internet connection deprives the disadvantaged of the benefit of the computer age. With the long term trend showing no slowing of internet adoption and utility, equitable access is imperative. To this end, we estimated the change in broadband cost over the next ten years, using . We concluded , which is significant because . We also predicted use of broadband by three different households over a year. This was modeled with logistic equations, and it shows us the trends for each of the . Finally, we built a model to efficiently space cell towers.

2 Question 1

We have found the dollar cost per MBPS per month, comparing wireless and wired internet from the United Kingdom and the United States. For this problem, we make the assumption that the rate of increase in internet speed is exponential, but that the rate of cost decrease is linear. This is consistent with the empirical data.

2.1 Model

Our model outputs four values: representing the cost of wired internet and wireless internet, in the United States and the United Kingdom respectively. This is displayed in the flowchart below. For our model, we found that the trend of the this equation would best model the speed trend for "Super Fast" internet in the UK:

$$f(x) = e^{(-250.6996+0.1262x)}(1)$$

Assuming the UK has "Super Fast" internet we can use the equation below to model the cost for internet where X is the year:

$$g(x) = -0.0036x + 91.167 \tag{2}$$

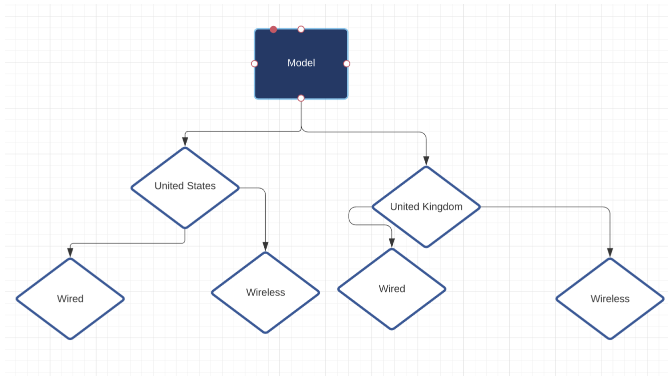

Figure 1: Flowchart of model

Using both we were able to find the equation for the wired costs of the UK

$$h(x) = \frac{g(x)}{f(x)} \tag{3}$$

Using UKWireless.R we were able to model the cost of UK wireless as the equation

$$n(x) = e^{(257.9915-0.1282x)} \tag{4}$$

To model the United States we were able to derive:-

$$y = mx + b$$

$$y - b = mx$$

$$log(y - b) = log(mx)$$

$$log(y) = log(a) + rt$$

$$y = e^{log(a)}e^{rt}$$

$$y = e^{(rt+log(a))}$$

$$x = -0.254710.012199$$

In 2012:

$$Speed = 28.7mbps(AvgPeakDS)$$

Closest to: Chattanooga, Tn 30 mbps in 2012 = 62.47/month
99 Confidence interval=0.12199
Let x = years

$$y = Cost/Speed = 2.08234 = e^{loga}e^{-0.2541(2012)}$$

$$log(a) = 511.98269$$

We get the equation to model the logistic curve that we use to model the United States cost per unit mbps

$$l(x) = e^{(511.982692261 - 0.2541x)} \tag{5}$$

Of which we use the equations...

$$l_1(x) = e^{(511.982692261 - 0.2541x + 0.12199)} \tag{6}$$

and

$$l_2(x) = e^{(511.982692261 - 0.2541x - 0.12199)} \tag{7}$$

To model the bounds of the logistic curve
To Model the US Wireless Speed we use the equation below

$$o(x) = \frac{n(x)}{h_1(x)} l(x) \tag{8}$$

Where n(x) is the UK Wireless equation, h(x) is UK Wired equation and l(x) is US Wired equation.
Finally, averaging all 4 functions we get:

$$p(x) = \frac{(\ o(x) + n(x) + l(x) + h_1(x))}{4} \tag{9}$$

3 Question 2

We are given the data from The Nielsen Corporation that that presents the numbers of hours a selected age group spends doing certain.

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

By incorporating the data from both 2017 Nerdwallet Report and 2019 CBT-Nuggets, we can convert the hours spent on a certain activity into gigabytes per hour.

Activity	Required Bandwidth
General web surfing, email, social media	1 Mbps
Online gaming	1-3 Mbps
Video conferencing	1-4 Mbps
Standard definition video streaming	3-4 Mbps
High definition video streaming	5-8 Mbps
Frequent large file downloads	50+ Mbps

Activity	Required Bandwidth
Minimum *required* speed for Netflix video streaming.	.5 Mbps
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

The "given below" represents the number we take according to what kind of quality the video could be. This way, we can factor in the quality of the streamed videos. However, since we only need to calculate the minimum value, it is not as important. For this question we will take the lowest quality streaming service.

Activity	2-11	12-17	18-34	35-49	50-64	65+
Watching Traditional Television	0.00	0.00		0.00	0.00	0.00
TV Connected Game Console(online gaming?)	1,312.5 - 3,937.5	1837.50 - 5512.50	1680 - 5040	727.5 - 2182.5	202.5 - 607.5	67.5 - 202.5
TV Connected Internet Device**	7,492.50 - 9,990.00	4,635.00 - 6,180.00	7,200.00 - 9,600.00	6,682.50 - 8,910.00	4,590.00 - 6,120.00	2,925.00 - 3,900.00
Internet on a Computer (not including video)	--	--	1,665.00	1,912.50	1,989.00	1,245.00
Video on a Computer	--	--	given below	given below	given below	given below
Total App/Web on a Smartphone(1)	--	--	11,100.00	11,257.50	8,790.00	6,015.00
Video Focused App/Web on a Smartphone()	--	--	given below	given below	given below	given below
Steaming Audio on a	--	--	315.00	255.00	165.00	90.00

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Watching Traditional Television	0.00	0.00		0.00	0.00	0.00
TV Connected Game Console(online gaming?)	1,312.5 - 3,937.5	1837.50 - 5512.50	1680 - 5040	727.5 - 2182.5	202.5 - 607.5	67.5 - 202.5
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Video Focused App/Web on a Smartphone()	--	--	given below	given below	given below	given below
Steaming Audio on a Smartphone(1)	--	--	315.00	255.00	165.00	90.00
Total App/Web on a Tablet(1)	--	--	1,965.00	2,715.00	2,752.50	3,202.50
Video Focused App/Web on a Smartphone()	--	--	given below	given below	given below	given below
Steaming Audio on a Smartphone(1)	--	--	45.00	67.50	45.00	37.50

We add up all the numbers in each age group to get the total amount of megabytes per hour for each week. Then we divide the total of each group by 7 in order to get the amount of megabytes per hour each day.

(Megabytes per hour)(1 day)	Age Category					
Activity(total bandwidth Megabyte per hour)	2-11	12-17	18-34	35-49	50-64	65+
from	1257.857143	924.6428571	2596.607143	2784.464286	2237.928571	13708.39286
to	1989.642857	1670.357143	3076.607143	2992.392857	2295.857143	15151.60714

$$q_1(x) = 0.0002x^4 - 0.0118x^3 - 2.0189x^2 + 165x + 296.33 \quad (10)$$

$$q_2(x) = -0.00002x^5 + 0.0057x^4 - 0.4952x^3 + 15.384x^2 - 74.767x + 1867.1 \quad (11)$$

$$q(x,t) = \frac{(q_1(x) + q_2(x))}{2} \pm - \frac{t(|q_2(x) - q_1(x)|)}{2}$$

(12)

$$T(x,t) = \sum_{n=1}^{m} d_i q_i(x,t) \quad (13)$$

q is the consumption in terms of age, and d is the number of days of the week that a person is being accounted for. T(x,t) therefore is the total consumption of the household where x is the ages of the people and t is the t-statistic for the confidence interval. We can do 99

4 Question 3

Question 3 saw us building a model to optimize the configuration of broadband towers. Our model allocates cellular nodes in a region using the characteristics of the population to help us determine the bandwidth needs of different subregions.

4.1 Model

We made our model based on the following assumptions: The population density is uniform within the subregions Cost of living index is 100Households of yearly income ¿ 75k have identical internet habits Each of the cellular nodes emit signals with a radial symmetry, so we can treat them as circles. The ratio of the radius of the signal emitted by each type of node to the area of the subregion gives a workable lower bound of how many nodes of each type should be in a certain subregion. The formula to find the number of nodes of a radius r to place in a region of area $A_{Ri} is$:

$$ceil[A_{Ri}\left(\frac{1}{\pi r^2}\right)] \tag{14}$$

Where ceil(x) is the ceiling function, i.e. it inputs real numbers and outputs the closest integer greater than the input. This formula is applied to all regions and for every type of node. Despite the simplicity of the formula, it covers most of the factors that would otherwise be considered.

Regions A, B and C

Region A has a total area of 6.83 miles. Using this as input to our model shows us we would need between 3 and 9 cellular nodes of radius 0.5 miles to 1 mile and one of each other node (of radius 2-3miles and of radius 10-20 miles). If we define type 1, 2 and 3 nodes in the order of increasing radius region A requires:
3 - 9 type 1 nodes
1 type 2 node
1 type 3 node
Region B has a total area of 33.64 square miles, returning:
11 - 43 type 1 nodes
2 - 3 type 2 nodes
1 type 3 node
Region C has a total area of 1.64 square miles, returning:
1 - 3 type 1 nodes
1 type 2 node
1 type 3 node

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