M3 — MathWorks Math Modeling Challenge 2021

A CONTEST FOR HIGH SCHOOL STUDENTS
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Defeating the Digital Divide: *Internet Costs, Needs, and Optimal Planning*

High-speed internet is for more than just entertainment, and those without sufficient access are at a significant disadvantage, especially when it comes to attending school remotely[1, 2], safely accessing healthcare[3], working from home, civic participation, information access, and more. Ensuring that everyone (particularly those in rural and low-income areas) has sufficient access to high-speed internet is a technical, logistical, and economic challenge[4, 5]. It is not clear which among the many ways to access the internet (e.g., cable, fiber-optic lines, satellites, mobile broadband) can best solve the connectivity issues experienced by people in different types of households and regions. Accessing the internet from a mobile device, such as a cell phone or a mobile hot spot, has been a helpful option for remote-learning students and others during the pandemic[6], but will mobile broadband be the future of high-speed internet access[7]?

- **Q1: The Cost of Connectivity**—Bandwidth, typically measured in Megabits per second (Mbps), comes at a cost. Build a model to predict the **cost per unit of bandwidth in dollars or pounds per Mbps** over the next 10 years for consumers in the United States and the United Kingdom.

- **Q2: Bit by Bit**—Create a flexible mathematical model to predict a given household's need for the internet over the course of a year. Apply your model to the example households listed below and determine the **minimum amount of required bandwidth** that would cover their total internet needs 90% of the time. What about 99% of the time?

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

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

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

  You may wish to account for global shifts in online education and changing patterns in online work.

- **Q3: Mobilizing Mobile**—Mobile broadband (e.g. 4G and 5G internet) is transmitted from towers or nodes[8]. Develop a model that produces an **optimal plan for distributing/placing cellular nodes** in a region. The model should incorporate information regarding population and demographic data for the region and should take into account the bandwidth needs of the region. Demonstrate the flexibility of your model in the three hypothetical regions provided (see the data provided) or substitute with regions of your choosing.

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1 https://parentzone.org.uk/article/children-left-behind-world-distance-learning

2 https://www.reuters.com/article/us-health-coronavirus-usa-education-feat-idUSKBN25O1XR

3 https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(20)30818-7/fulltext

4 https://www.totaltele.com/505321/What-are-UK-operators-doing-to-support-their-customers-during-the-COVID-19-pandemic

5 https://www.consumerreports.org/broadband-access/covid-19-relief-package-will-help-families-in-need-of-internet-access/

6 https://digitalbridgek12.org/toolkit/research-options/connect-your-students-to-internet/

7 https://arstechnica.com/information-technology/2019/12/5g-as-a-home-broadband-replacement-isnt-a-slam-dunk-yet-but-it-might-be-soon/

8 https://www.verizon.com/about/news/towers-what-they-are-how-they-work

MORE ON REVERSE

Your submission should include a one-page executive summary with your findings, followed by your solution paper— for a maximum of 20 pages. If you choose to write code as part of your work to be eligible for the technical computing prize, please include it as an appendix and check the box on the upload page. Cite your sources, including those in the provided data files if you use them. Any code appendix or reference page(s) will not count toward your 20-page limit.

Data Statement:

Various organizations and agencies collect data on a regular basis. A small amount of data has been compiled and a link to an excel spreadsheet with multiple worksheets of data is provided and summarized below. You are not required to use this data; that is, you may choose to use none, some, or all of this data and/or any additional data sources you may identify while working on this problem. Data sets in the real world are often incomplete or contain holes. Be sure to cite all resources used.

To cite any of the data below:
Defeating the Digital Divide Data, MathWorks Math Modeling Challenge 2021, https://m3challenge.siam.org/node/523.

The following data are in a spreadsheet, with tabs marked accordingly. Find that spreadsheet here: https://m3challenge.siam.org/node/523.

Data relevant to Question 1:

    [D1] Average bandwidth in the US and UK
    [D2] Cost for Bandwidth (US, wired)
    [D3] Cost for Bandwidth (UK, wired and wireless)

Data relevant to Question 2:

    [D4] Internet Media Consumption
    [D5] Bandwidth requirements for various activities
    [D6] Online education statistics
    [D7] Work from home statistics

Data relevant to Question 3:

    [D8] There are sets of hypothetical population data and maps for three regions, Region A, B, and C, based loosely on data for three actual regions.
    [D9] Mobile broadband frequency band characteristics.

MATLAB Users:

If you are trying to use Excel or any other spreadsheet data in MATLAB, you can import the data by double-clicking the files in MATLAB's "Current Folder" browser or use the Import Data Button (https://www.mathworks.com/help/matlab/spreadsheets. html?ue) at the top of the Toolstrip.

Watch this quick MATLAB video tutorial (https://www.youtube.com/watch?v=0hArv-UBKQQ&list=PLn8PRpmsu08oBSjfGe 8WIMN-2_rwWFSgr&index=14) about importing spreadsheet data.

See how the MATLAB Import Tool (https://blogs.mathworks.com/cleve/2018/10/05/mathworks-math-modeling-challenge/#just-eat-it) was used in a previous year's problem to import and analyze data.