

Level	<h1>Who Decides if you get 5G?</h1>	
High School		
Time Required	Lesson Summary	
150 min. (3 - 50 min. class periods)	<p>During this lesson, students will discover what 5G phone coverage is and develop an understanding of why some areas have it while others do not. Students will get hands-on experience with the frequency allocation table by participating in an activity that will guide them to a deep understanding of spectrum users. Students will then learn about how allocation rules are challenged. They will take one of three positions on the topic of 5G and debate the most appropriate use of certain frequencies. Finally, students will learn about the economic side of 5G as the class discusses spectrum auctions.</p>	
Standards		
<p>NGSS HS-PS4-5 Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy</p>		
Vocabulary	Objectives	
Allocation Fixed Mobil Radiolocation	<ul style="list-style-type: none"> <li>• Students will understand the pros and cons of 5G service and why the wave behavior at these frequencies makes it impossible to put everywhere.</li> <li>• Students will understand how wave properties affect the devices that can use them and therefore the allocation process.</li> </ul>	
Materials		
<ul style="list-style-type: none"> <li>• Student handouts</li> <li>• Articles for debate</li> <li>• Allocation puzzle pieces, either buy the poster or print out the pieces and laminate</li> </ul>		

## Pre-Requisites

Students should be familiar with the electromagnetic spectrum and especially the radio frequency portion of the spectrum.

## Safety Considerations

None

## Pacing Notes

Day one – Research into 5G, class sharing session, explanation of allocation, Clothesline activity, debate group assignment

Day two – complete debate preparation

Day three - debate

## Before the Lesson

Either purchase the poster (approximately 6 weeks for delivery) or print and cut out puzzle pieces. Print all student pages.

### Assessments

### Classroom Instructions

#### Pre-Activity Assessments

#### Introduction

By allowing students to do the research on their own you are reinforcing that skill. Reading the articles and pulling out key information meets literacy standards.

What is 5G and why do we want it?

Cell phone companies have made commercials advertising their 5G networks and making us think we want this service. But what is 5G and how is it different from what most of us already have (4G)?

While you are taking attendance have students research this question. If you want you could place a few web pages on your class webpage and have students use those for their research but it is easy to find suitable web pages just using the Google search box. There are some suitable web pages listed in the *Teacher Resources* section below.

#### Activity Embedded Assessments

#### Activities

- I. Class list of why 5G  
Put students into groups of four. Have them discuss their research and create a group list of the pros and cons of 5 G.

Then go around the room and have each group contribute one of their answers which have not been shared yet. Have a student write the reasons on the board.

Remind students that just because we want something it doesn't mean we can have it. Remind students that cell phones use radio frequencies to communicate. Explain that the federal government assigns certain uses to specific frequencies through a process called allocation.

2. How uses are assigned frequencies
  - a. Radio Frequency Allocation Clothesline (~30 min.)

**Say:** Radio frequencies are a very valuable commodity allocated and monitored by the Federal Communications Commission like real estate. Companies like T-Mobile and Verizon pay TENS OF BILLIONS of dollars for relatively small areas of bandwidth! Meanwhile opposers to the growing field, such as those in science and the airline industry, say the sharing of frequencies is causing harm.

Take any questions, if needed here.

**Say:** Let's see just how much space we have in the radio frequency range. In a moment we will get into groups to investigate how the radio spectrum is divided up, but first we need to understand our roles in the groups.

Pass out the activity worksheet, Radio Frequency Allocations, included with this lesson. Have the students complete the first questions about radio wave uses. Remind them to stop and listen to the directions before working ahead of everyone. When they are done with the first question, continue:

**Say:** At the top right side of your sheet you will see the group member jobs. The Reader is in charge of understanding the numbers on the cards, and will know how to put the frequencies in the correct order. The Runner will be the only student in the group who can get out of their seat. They will place the cards on the wall or get supplies as needed. The Speaker is the only member of the team who can speak out for the team, including asking for help or telling the runner what to do. Finally, the Captain is in charge of the team and keeping everyone in line. They make sure all are participating and follow the rules of their job. Keep in mind some people may need to take on more than one job if your group is smaller than four people. Are there any questions?

Allow the teams to calmly get into groups of 3-4. They can begin to fill out the Group Members and Jobs section on their page. Once the groups are settled, review the Objectives of this activity listed in the bottom left side of their worksheets. Students should have a clear idea of why they are

doing this exercise.

**Say:** Now in a moment, I will pass out the cards. These cards will show a radio frequency range and the activities allowed at that range. Make sure everyone in your group can see what is written on each card, and then the Reader will put the cards in order of increasing frequency at your table. Be sure to pay attention to the units, such as Megahertz or Gigahertz.

Pass out the US Frequency Allocation Chart cards as evenly as possible to each group. These cards should be from various sections of the spectrum and of varying difficulty. As the groups receive their cards, remind them that all members of their group should be allowed to read them, and the Reader should kindly explain to their teammates how they can determine the order of their cards from low frequency to high. Walk around and check on the groups as they work, asking questions such as, “Which is bigger, Gigahertz or MegaHertz?”, and checking to make sure all students in a group can explain the process for sorting the cards. When they have sorted the cards, proceed with the next step.

**Ask:** What are some of the uses you are seeing in your cards for radio waves?

Allow students to call out answers and write them on their papers in Part I. Provide clarification on activities they might have heard of but are not known to everyone, such as “aeronautical radionavigation”, “fixed”, and “amateur”. The teacher can display the Radio Services Color Legend after students are done volunteering answers. Clarify any questions they may have before moving on.

Before the class arranges the whole spectrum in order, be sure to explain the clothesline activity clearly. It will help to minimize chaos if the beginning of the spectrum is done with guidance as an example.

**Say:** Everyone has cards from different parts of the radio spectrum. We will now put our cards up on the wall in order of lowest to highest frequency to see how long this spectrum is altogether. Let’s see which group has the card with the lowest frequency! Who has 0 kHz?

The group with the 0 kHz card will send their Runner to put the card on the wall. Ask the Runner what is the ending frequency on their card, and repeat that frequency so the class can hear. Let the first runner return to their seat. See which group will have the next card in the sequence, but do not have them run the card to the wall yet.

Note: The class can complete the activity in the classroom on the wall/board or, with permission from an administrator, take the activity to the hallway or another large area if the class understands how to behave. If

Collect and grade the Radio Frequency Allocation sheet

Given the nature of a debate, this is not a learning activity that should be graded. If you would like to give a grade for this part of the lesson consider assigning a writing assignment based on the debate.

there are lockers lining the hallways at school, students can use magnets to hold their cards in place. Otherwise use tape or make a clothesline with enough clothespins for the number of cards.

In total, the clothesline will probably be more than 20 feet long! The teacher can hang multiple rows so there is enough room for all the cards, but be sure the students understand the order of the frequencies placed in multiple rows.

**Say:** Before we finish hanging our cards, let me repeat the expectations. I will say the frequency we are on out loud for the class to hear. The teams, especially Readers, will listen and see if they have the next card. If your team has that card, you will send your Runner with the card so we can hang it up. I will check and if it is the correct one, I will read out the next frequency. Remember, only the Speaker of your group can speak louder than a whisper for this game, and only the Runner can walk around. Captains should be making sure everyone is on the right task. Does anyone have any questions?

Answer any questions or add any instructions as needed for the class, such as if the class will move outside of the classroom. Announce the next frequency again for the class, and continue the game until all the cards are in order.

**Say:** Great job, everyone. What are you seeing about the radio spectrum that you didn't know before?

Allow students to respond to this question out loud regardless of their jobs within their groups. Point out any interesting uses on the spectrum that they may not have noticed earlier, and ask questions about their interpretation of the busier parts of the spectrum. "Why do you think this area is so crowded?" Have volunteers help take down the cards if needed, and have the students complete the rest of their worksheets.

b. Challenges - debate

Assign students to read one of the following articles as homework. You can either allow students to choose an article or assign each student to read a specific article. If you allow students to choose try to keep the three groups as similar in size as possible. Tell students that they will be taking the side of the group portrayed in the article.

Cell phone companies

<https://www.lifewire.com/5g-spectrum-frequencies-4579825> (last accessed June 5, 2023)

Military

During the debate, pay attention to students' responses. If a student provides incorrect information, don't intervene. Instead, allow the other students to correct the misinformation. If the information persists despite several students chiming in on the matter, step in and correct the misconception.

<https://www.defense.gov/Explore/News/Article/Article/2404027/new-spectrum-strategy-reveals-dods-plan-to-master-airwaves/> (last accessed June 5, 2023)

Researchers

<https://www.aip.org/fyi/2019/scientists-wary-interference-impending-telecommunications-initiatives> (last accessed June 5, 2023)

Today the students are going to participate in a debate. It is the teacher's choice if this debate is held as a whole class or in small groups. Regardless of the size of the debating groups it is important that you specify the rules of the debate before starting the activity.

Students should only be allowed to speak one at a time. They should always provide a reason for their position which is backed up by evidence from the readings. It is okay for them to disagree but they need to do so in a respectful manner. Consider providing a list of sentence starters to help students find the correct words to interact with their peers.

The main question of the debate is:

Should companies be allowed to use the same frequencies as researchers and the military?

Remind students that they should be supporting the position in the article they were given to read.

If the discussion wanes interject additional, related questions for the students to discuss.

Post Activity Assessments

Closure

The last step in spectrum allocation is auctioning off the spectrum. Explain to students that telecommunication companies like Verizon, At & T, T-Mobile, etc. have to purchase the right to use the spectrum from the government. Frequencies are auctioned off to the highest bidder. It is not uncommon for these to sell for hundreds of millions of dollars. Explain that for a company to be willing to spend that money just to get the ability to use those frequencies there has to be a benefit to them. That benefit is how much they can get in return by selling the service to people. The more people that live in an area the higher return they will get on their investment.

## Culturally Inclusive/Responsive Components

Have students investigate telecommunications companies from around the country or the world. They should determine how those companies are developing services for their customers. You can then have a discussion about the similarities and differences the students discover.

## Educator Resources

<https://www.techtarget.com/searchnetworking/definition/5G> (last accessed June 5, 2023)

<https://www.pcmag.com/news/what-is-5g> (last accessed June 5, 2023)

<https://www.fcc.gov/5g-faqs> (last accessed June 5, 2023)

## Optional Extension Activities

The closure discussion could be expanded to a discussion about inclusion. Students could create a plan to make offering 5G to everyone beneficial to the telecommunications companies.

## Acknowledgment

The creation of the lessons in this series was funded by a generous grant from the National Science Foundation (NSF). The lessons were created as part of the SpectrumX project at the National Radio Astronomy Observatory (NRAO).

Below is a list of the lesson titles included in the series. All lessons can be accessed from this web page, <https://superknova.org/educational-resources/>.

### Middle School

Introduction to Satellites

Weather Predicting

Introduction to Radio Wave Communication

The Importance of Radio Astronomy

Cubesat Model Building

Understanding FM Radio

Radio Frequency Technology

Who Decides if You Get 5G?

### High School

The Uses of Radio Waves and Frequency Allocation

Is Radio Technology Safe?

Diffraction of Radio Waves  
Measuring Sea Surface Temperatures with Satellites  
Marine Animal Tracking and Bathymetry  
How to Design Your Own Crystal Radio  
How Radio Waves Changed the World  
Simple Wireless Communication  
Seeing and Hearing the Invisible  
Local Wireless Radio Frequency Communication  
Investigating the Internet Connection  
The Geometry of Radio Astronomy

**Informal**  
Modeling Radio Astronomy

