Networks

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Lesson Focus

Young people take the Internet for granted. Through a serious of web-based explorations and kinesthetic exercises students explore the basic principles of graph theory and how it applies not only to their social connections but to how information is passed around.

Age Levels

Recommend for ages 11 – 13

Objectives

Introduce students to:

- How basic graph theoretic concepts are essential to the Internet.
- How information is moved around a network.
- How traffic on the Internet can be monitored.
- How social media networks provide access to personal information.

Anticipated Learner Outcomes

Students will be able to demonstrate/explain how:

- A connected graph provides reliable service.
- Information can be reliably moved from place to place with packets.

Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

Internet Connections

Videos

- https://www.youtube.com/watch?v=i5oe63pOhLI
- https://www.youtube.com/watch?v=oj7A2YDgIWE (essential concepts require)
- https://www.youtube.com/watch?v=scWj1BMRHUA (history optional)

Traceroute:

- http://www.internetsociety.org/internet/how-it-works/technical-aspects https://mediatemple.net/community/products/dv/204643870/using-the-traceroute-command#3
- https://itunes.apple.com/us/app/inettools-network-diagnose/id561659975?mt=8
- https://play.google.com/store/apps/details?id=com.scan.traceroute&hl=en

Recommended Reading

- (A wonderful overview of graph theory in action.)
- http://www.americanscientist.org/issues/pub/graph-theory-in-practice-part-i/99999
- http://www.americanscientist.org/issues/pub/graph-theory-in-practice-part-ii/99999

- http://web.stanford.edu/class/msande91si/www-spr04/readings/week1/InternetWhitepaper.htm

Optional Writing Activity

- You have learned how the Internet moves information from place to place using routers and packets. Explain how and when things can go right and when they can go wrong.

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For Teachers: Teacher Resources

Lesson Objectives

- Introduce the basic graph theoretic concepts essential to the Internet (vertices and edges).
- Demonstrate how connectivity is achieved through routers.
- Provide an experience that illustrates how packets move on the Internet.
- Provide background for a discussion on the features (and liabilities) of social media.

Materials

- Access to videos online. Download and cache ahead of time if necessary.
- Access to computers through which your students can
  - Do Internet research
  - Use the 'traceroute' tool (see procedure).
- Objects that can be passed around a network (small box, ball, textbook, etc).
- Unlined, white index cards, sufficient for each student to have 9, plus extra for lost or damaged cards. Post-It notes may also be used, but cards are more resilient.
- At least 50 index cards, preferably not white; or use large 'Post-It' notes (3X3).
- Drawing implements: colored pencils, crayons, markers, etc.
- Blue painters' tape (1 inch wide) for marking a graph on a surface large enough for all of your students to be at least 3 feet apart (gym, playground, hallway). Regular masking tape will do, but isn't as visual.
- A black or white board, or poster board, upon which students can create a graph which traces a route from their school to an Internet location.

Procedure

This activity assumes that you and your students can access the Internet to (1) watch videos, (2) do research via search engines such as Google, (3) use a utility called 'traceroute'.

Prepare ahead to determine what technology will work best for you. If students are using personal devices, you may need to ask them to get permission from their parents to download the necessary software. You may need to work with your IT staff to provide access to 'traceroute' on student computers. Resources for installing 'traceroute' are listed under Internet Resources. If this is problematic or time sensitive in your school, be resourceful and choose among these other options:

- Have it installed on your teacher workstation, or install it on your personal device. You will need to carefully schedule groups of students to use the device.
- If your students have school issued tablets, have 'traceroute' installed on them.
- If even there are only three or four available smart phones, get parent permission to install it on those devices.

You will need to assign students to create a message or drawing for another student in your class. It is best to assign recipients ahead of time so that each student both gives and receives a drawing. Depending on your class, create sufficient extra drawings that can be assigned at the last minute due to student absence, lost drawing etc. The sender and recipient should not be a pair, e.g. if John is sending to Mary, Mary should not send to John.

You will need a space large enough for the students in your class to become a human network. This lesson assumes you have at least 6 students, although it will work best with at least 12. Recruit volunteers from elsewhere as necessary. Make it a school event.

The human network activity in Session 2 works best if sender and recipient are not near each other. You can do this efficiently if you create a numbered list of your students, preferably not in alphabetic order. The number assigned to the student will be their vertex position in the human network. Randomly assign a student in the first half of the list to send a message to a student in the bottom half. Start assigning in the middle to help create a good spread. Assign the student in the second half of the list only to those in the first.

Finally you will need a black or white board or other vertical space upon which your students can create a graph. You will need a horizontal area of at least 8 feet.

Session 1: Worksheet 1

- Choose the most appropriate video for your class from those listed in Internet Connections, and have them watch it at the start of the session (or assign it for homework before the session).

- Have a discussion (10 minutes max) about how packets are moved around the Internet. Like the post office, or parcel delivery service, there are distribution centers (post offices) and delivery routes that fetch and deliver letters and packages and move them from town to town. Use the illustration on Worksheet 1 as a guide. The key concepts are:
    a. The Internet is a *network* of *routers* that direct how *packets* of information get from a *source* to a *destination.*
    b. A *network* is a *connected graph* where *routers* are *vertices,* and links between routers are *edges of the graph.*
    c. Information is split up into *packets.* Each packet is marked with a source, a destination and instructions on how to reassemble the information.
    d. If an *articulation point* is removed from a graph, then some vertices are no longer connected to others. Stable networks do not contain articulation points.

- Split your class into groups of six. Distribute the remaining students between the existing groups. (Plan ahead and assign groups in a way that supports cooperation in your class.) Have the students use blue painters' tape and Post-It notes to create their network as specified in Worksheet 1. Groups with more than six can add vertices and edges as they see fit. Have them complete the worksheet. Supervise execution and explain the importance of understanding the vocabulary for the larger event coming in the second session. Leave time for cleaning up!

- Distribute to each student Worksheet 2, with 9 new index cards. As per the worksheet instructions, have them lay out their cards as a 3X3 grid, and mark the cards as shown on the worksheet. Have them flip each card over so that it remains in the same position in the grid. Have them draw a picture, or write a letter using up the space on all nine cards. Have them complete this exercise in class and make sure to collect one set of cards for each *recipient.* As students complete this,

have them proceed immediately to step 5.

- Have pairs or triples of students use the Internet to research the answer to the question on Worksheet 2: "How does social media work?" Have them write a short answer that fits on the Post-It along with their names and the link (URL) to the resource from which they got their information.

- The remaining task can be done in a number of ways depending on time, and the technical competence of your students. Ideally, have pairs or triples run 'traceroute' on the address of their best resource, and using whatever technology they can, have them capture the 'traceroute'. They can print it, screen capture, or even take a picture of it with a smart phone. Please make sure they have a copy they can carry with them during step 3 of Session 2. It is best if at least three groups finish this task. Assign it for homework if necessary, so that as many students as possible can actively participate in the Session 2 activity.

Session 2:

1. Using Worksheet 3 as a guide, have your students create a network with the number of nodes based on the size of your class. Assign each student to a vertex number. Lie down and number the vertices, first using the non-white index cards or Post-Its, and distribute sufficient blue painters' tape so that groups of students can create the edges that connect them together. Each student will be responsible for his or her edges. Distribute the sets of cards to each person who made one. Prepare a few extras for sets that may get lost, so that each participating student has a set to send and, more importantly, a set to receive.

2. Have your students place themselves on the network. (You might want to arrange to have this activity video-taped.) Explain that when you give the signal, the goal is for the whole group to get all of their cards (packets) to their destination as quickly as possible. Only one card can be handed off at a time. It is within the rules to look at which direction to send a packet (card) to get it there most quickly. Tell the class "When cards come to you, send them on as quickly as you can. When you receive a card that is for you, put it face down on the floor placing it in the right spot." When everyone has received their cards, and the noise has settled down, everyone gets to flip over their cards and read the message from their friend.

3. **There is no worksheet for this task - it relies entirely on your instructions.** Move to the space that contains your black or white board or poster board (or butcher block paper on the floor). Distribute to the pairs or triples the 'traceroutes' they prepared in the first session as well as their index card about social media. Pick one team to begin writing (in small print on the left edge of the space) their initial location. Have them move to the right and print the next address, drawing a line between the two addresses. Have them continue moving across so that their index card is posted at the final spot on the right side of the board. Have the next group start to print on the left edge below the first group as the first group moves on. Continue with all groups until everyone has completed the task.

   If you are using a poster board instead of an erasable board, have the students write the IP address on Post-Its rather than directly on the poster board. Do not

have them draw edges yet.

4. With the entire class, study the board to see whether any of the routes used the same intermediate addresses. Combine vertices and redraw edges when you find duplicates. If you used a poster board or butcher-block paper, this is the time to draw edges between vertices.

5. As an entire class, have students discuss how many hops it took to get to the research URLs. What is the shape of your network? Were there particular sites that most (or all) of them touched? What other insights can they see in the network? Have a discussion about how people are connected on social media and how the Internet supports social media. Note that there are no right answers here, and the goal is to simply get them thinking about how this all works.

- **Time Needed**
  - 2 sessions, at most 1 hour each. This can be done in a single two-hour session if your students are typically cooperative in physical activities. If not, please consider laying out the large graph (worksheet 3) ahead of time. Demonstrate Session 1, step 2, using the first six vertices, and have the other students watch. Alternatively assign the video and the Internet research activity (Session 1, step 4) as out-of-class activities. This assumes that 'traceroute' is available. If your class periods are shorter than an hour, you may need a third session to do the final 'traceroute' activity.

Networks

Student Resource:

In this lesson you are going to learn how information moves around the Internet.

You will also be asked to send a message or draw a picture for someone in your class. Courtesy and kindness are expected, whether or not this person is your personal friend. You will also be receiving a message from someone else, and you should expect the same from them.

You will view a video in which you will learn about:

- Networks _____
- Routers _____
- IP addresses _____
- Packets _____

Write definitions for each of the above on the space provided.
You will become part of a human network which will require knowing some other concepts that are not presented in the video. A network is a kind of 'graph', not like the ones you draw to represent data. Here is a summary of the vocabulary:

- The Internet is a *network* of *routers* that direct how *packets* of information get from a *source* to a *destination.*
- A *network* is a *connected graph* where *routers* are *vertices,* and links between routers are *edges of the graph.*
- Information is split up into *packets.* Each packet is marked with a source, a destination and instructions how to reassemble the information.
- If an *articulation point* is removed from a graph then some vertices are no longer connected to others. Stable networks do not contain articulation points.

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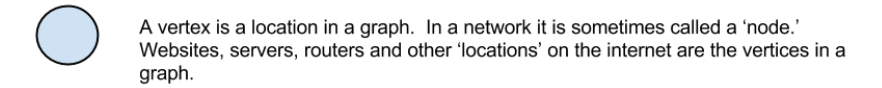
Student Worksheet 1: A Small Network

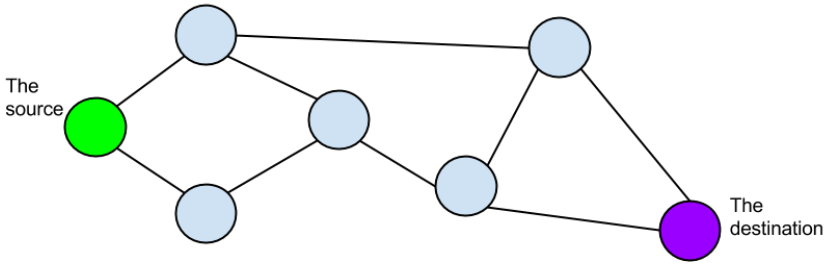
Your teacher will assign you to a group of about six people. Your job is to create a network, on the floor, based on the drawing below. You will each stand on a vertex and move a packet from the source (in green) to the destination (in purple). Place Post-Its on the floor as the vertices, about 2 or 3 feet apart so that you aren't climbing all over each other. Use blue painters' tape to mark the edges. If you have more than six people add vertices and edges so that everyone is connected.



A vertex is a location in a graph. In a network it is sometimes called a 'node.' Websites, servers, routers and other 'locations' on the internet are the vertices in a graph.

Edges connect the vertices. Edges on the internet are sometimes called 'connections.' Connections occur through DSL, copper-wire, fiber-optic cable as well as wireless connections. For information to move around the Internet it has to travel alonge edges.

Please create a graph like the one below. If you have more than six people add a vertex to the graph, and connect it to at least two of the existing vertices.



Each member of your group should place themselves on a vertex. Simulate moving a packet from the source to the destination. Your teacher will give you an object to represent your packet. Try it a few times. Answer the following questions on the back of this sheet.

1. What is the shortest number of 'hops' your packet needs to take to get from the source to the destination?

2. What is the longest path it could take, if it doesn't loop or return to the source?

3. Is there any vertex that is an articulation point, that is, if it were removed, the packet couldn't get from the source to the destination? What if you remove a vertex, does this create an articulation point?

4. Can any vertex be a source that gets a packet to any destination?

Networks – Beyond Social Media

Student Worksheet 2:

Creating Packets:
Your class is going to participate in one large human network. Each of you will send a message or a drawing to someone else using 9 packets of information.

Your teacher will tell you who your recipient is. Write this name here: _____

You will receive 9 index cards on which to write your message or create your drawing. Lay them out in a 3 X 3 grid and label them as shown. When you have completed labeling the cards, flip each over keeping it in its position in the grid. Create a message or simple drawing that covers all of the cards. When you are finished, collect your cards, shuffle them, and give your collection to your teacher. Don't let anyone see your message.

1,1 To: Your recipient's name From: Your name	1,2 To: Your recipient's name From: Your name	1,3 To: Your recipient's name From: Your name
2,1 To: Your recipient's name From: Your name	2,2 To: Your recipient's name From: Your name	2,3 To: Your recipient's name From: Your name
3,1 To: Your recipient's name From: Your name	3,2 To: Your recipient's name From: Your name	3,3 To: Your recipient's name From: Your name

Internet Research:
Your teacher will give you a Post-It note for this activity. To participate in the final activity in the next session, you will need to complete this task:

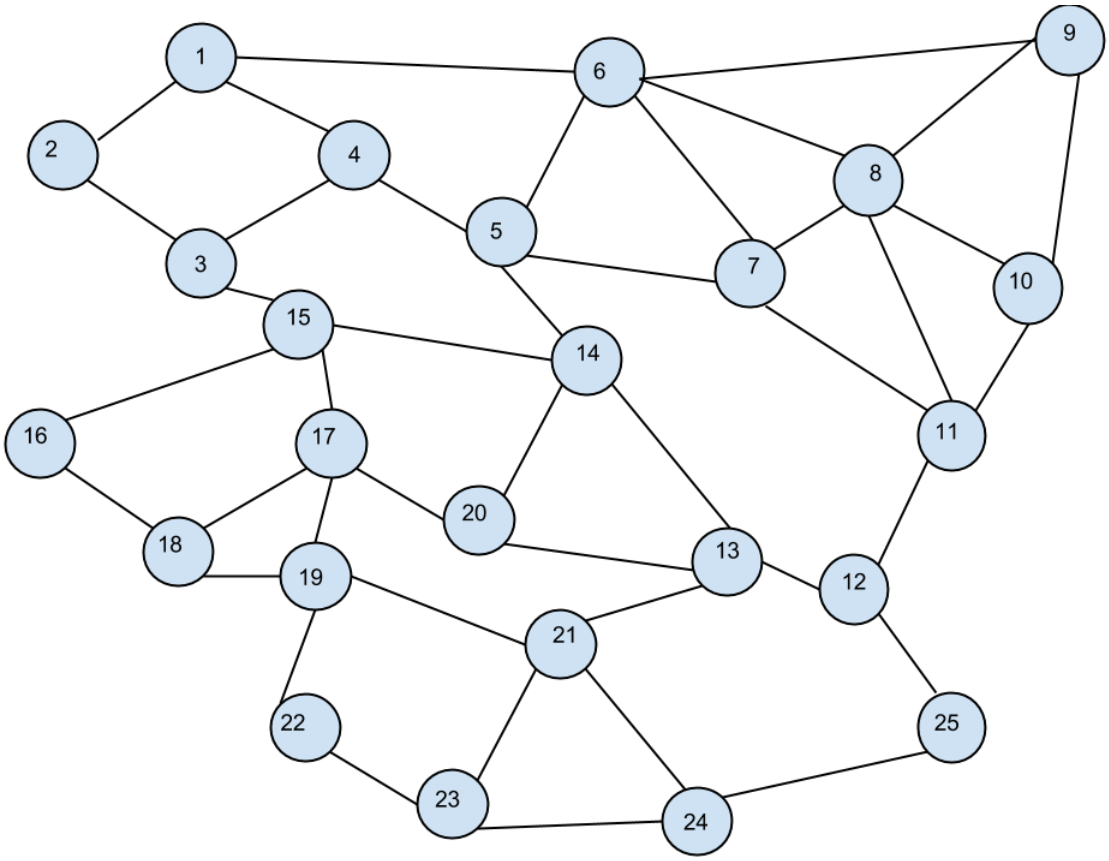
1. Put all of our names on the card leaving enough space for steps 2 and 3.
2. With a partner or in a team of three, use a computer, tablet, or smart phone to research the question "How does social media work?". When you've found a site you like, write down the address (the URL) for the site. Your teacher or another student can help you find this if you don't know how to locate it.
3. In the remaining space explain how social media works.

Traceroute
Your teacher will give you directions on how to run a 'traceroute' on your computer, tablet, or smart phone. Do a 'traceroute' on the URL you wrote down in the previous task. Your teacher will tell you how to capture the trace so that you have it with you during the second session.

A Big Network

Your class is going to build one big network using Post-It and painter's tape, based on the number of students in your class. Use the graph below as a guide, or follow instructions from your teacher. (He or she may add vertices in particular places or let you add them as needed.)

When your graph is complete, collect your packets from your teacher, get your assigned vertex number and stand on that vertex. When your teacher gives the signal, start passing your packets, **one at a time,** via your edges to your neighbors. Others will pass packets to you. Pass them on if they don't belong to you. It is in the rules that you can choose to pass information in the direction of the person to whom the packet is addressed. Once packets are no longer traveling around the network, your teacher will give the signal to assemble your packets into a message. Enjoy!



If there is time, your teacher will take out at least one node and have you rerun the packet delivery. Or as an exercise as a group, discuss which nodes are critical.

For Teachers:

Alignment to Curriculum Frameworks

Note: All lesson plans in this series are aligned to the Computer Science Teachers Association K-12 Computer Science Standards, and if applicable also the U.S. Common Core State Standards for Mathematics, the U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics, the International Technology Education Association's Standards for Technological Literacy, the U.S. National Science Education Standards and the U.S. Next Generation Science Standards.

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Understandings about science and technology

◆Next Generation Science Standards & Practices Grades 6-8 (ages 11-14)

Practice 2: Generating and Using Models

- Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Practice 5: Using Mathematics and Computational Thinking

- Use mathematical representations to describe and/or support scientific conclusions and design solutions.

Practice 6: Constructing Explanations and Designing Solutions

- Construct an explanation using models or representations

◆ Principles and Standards for School Mathematics Gr. 6-8 (ages 11 - 14)

Geometry Standard

- Use visualization, spatial reasoning, and geometric modeling to solve problems
  - use visual tools such as networks to represent and solve problems

◆ Principles and Standards for School Mathematics (all ages)

Problem Solving Standards

- Solve problems that arise in mathematics and other contexts

Communication Standards

- Communicate their mathematical thinking coherently and clearly to peers, teachers and others

Representation

- Use representations to model and interpret physical, social and mathematical phenomena

◆Common Core State Practices & Standards for School Mathematics (all ages)

- CCSS.MATH.PRACTICE.MP1 Make sense of problems and persevere in solving them.
- CCSS.MATH.PRACTICE.MP4 Model with mathematics.

◆ Standards for Technological Literacy - all ages

Nature of Technology

- Standard 2: Students will develop an understanding of the core concepts of technology

The Designed World

- Standard 17: Students will develop an understanding of and be able to select and use information and communication technologies

Networks

For Teachers:
Alignment to Curriculum Frameworks

◆CSTA K-12 Computer Science Standards Grades 6-9 (ages 11-14)

5. 2 Level 2: Computer Science and Community (L2)

- Computational Thinking (CT)
  8. Use visual representations of problem states, structures, and data (e.g., graphs, charts, network diagrams, flowcharts).
- Collaboration (CL)
  3. Collaborate with peers, experts, and others using collaborative practices such as pair programming, working in project teams, and participating in group active learning activities.
- Computers & Communications Devices (CD)
  6. Describe the major components and functions of computer systems and networks.