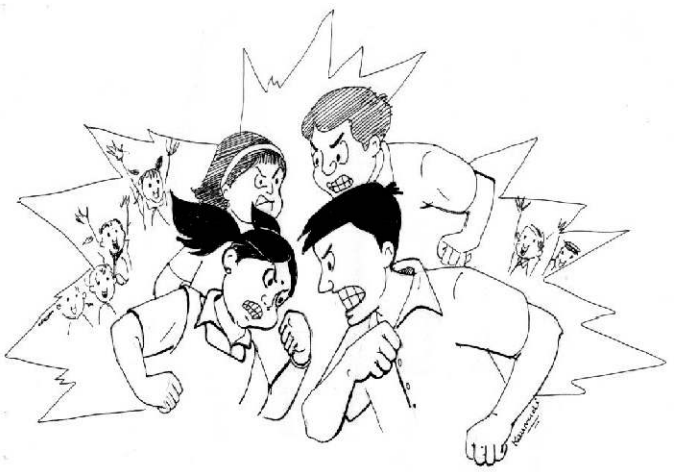
~ The Tracking Game~

Written by:
Sridhar Iyer,
IIT Bombay

The farewell party for the passing out batch was going on in the school grounds. It was evening and all the teachers were also relaxed. Various competitions had been held and two of teams were tied for the winning position. One team - Rahul and Rehan - had won most of the literary events, while the other team - Reva and Richa - had won most of the cultural events. The entire batch was taking a keen interest in the outcome of the final event since there was an element of 'boys versus girls' in the competition.



The final event was a tracking game devised by one of the science teachers, Mrs. Thomas, who was known for her ability to combine fun with learning. "Okay everybody, listen carefully. This tracking game has two parts.", she said, "The first part is similar to a treasure hunt. The first location is the principal's office. Here, only one person from each team will be given a clue to the next location, which will be one of the classrooms. He/She has to solve the clue to know the classroom location and go there. Here the person will be given another clue and so on. The treasure is at the sixth location. The clues are very simple and you will not need more than 15 minutes to reach the fifth location. However, at the fifth location you will not be given any further clue, so you will have to wait there." "What happens next?", asked the teams.

"Next comes the second part of the game - tracking. 15 minutes after the first person has left on the treasure hunt, the second person of each team will be given a message. He/She has to track and find the first person (who is by now waiting at the fifth location), and deliver the message. The message contains the instructions for finding the treasure. Together, they have to find the treasure and bring it to the principal's office. Whichever team takes lesser time to return with the treasure, wins.", she explained. "The catch is: No clues will be given to the second person. So the team has to devise a way to ensure that the second person can track and find the first person." she concluded with a mischievous smile.

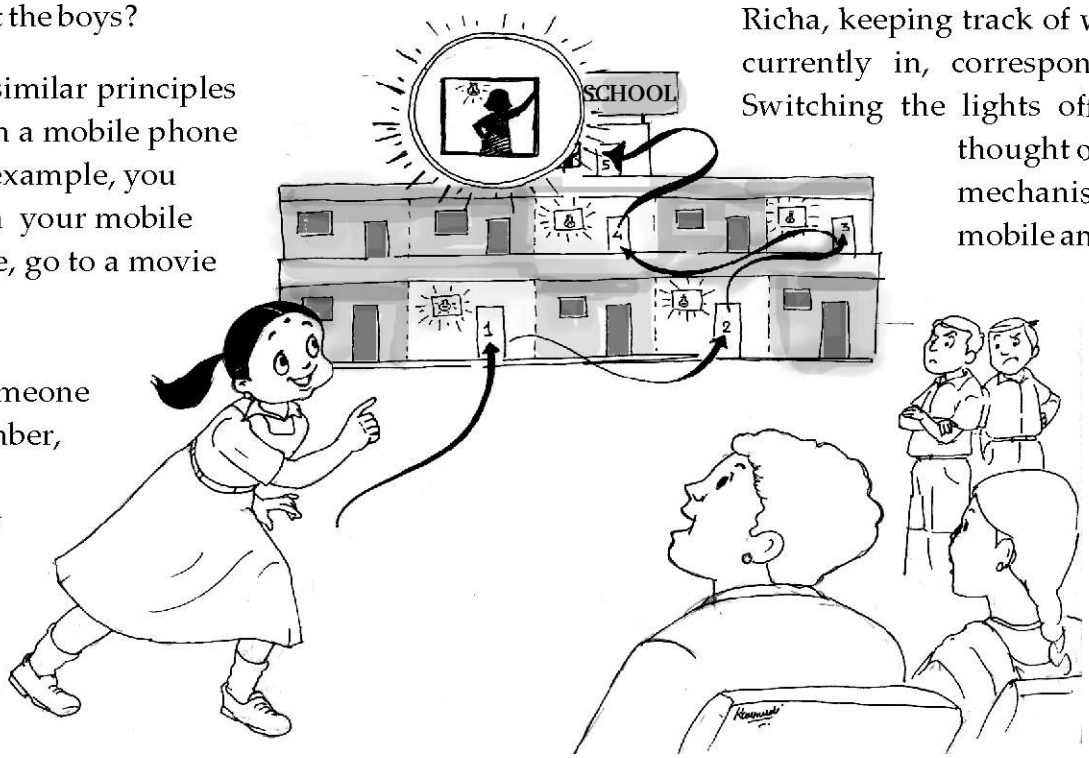
"That's easy. I'll just call Rahul on his mobile phone and ask him where he is waiting!", said Rehan jokingly. They all knew that the use of mobile phones was not allowed in the school premises and that they would have to find some other way.
"You could also search through the entire school and look in each classroom till you find Rahul", said Richa, knowing that such a way would be very inefficient. Each team knew that in order to win the competition, they would have to devise some way by which the second person could quickly locate the first. Can you think of any?

Here is what Rahul and Rehan did: Rahul did the first part - treasure hunt. He solved the clues one by one and reached the fifth location. However, before leaving any location (for example, classroom 3A), he wrote his next destination (for example, classroom 7C), on classroom 3A's blackboard. Similarly before going on from 7C, he wrote his next destination on 7C's blackboard. Thus he left a trail for Rehan to follow. After 15 minutes, Rehan did the second part - tracking. He went to the first location (3C), and found the next location (7C) written on the blackboard.

He went to 7C and looked at the blackboard to get the next location. Thus he simply followed this chain and found Rahul waiting in the fifth location. They then solved the last clue and returned with the treasure. It took them less than 20 minutes from start to finish.

What were Reva and Richa to do? They had to find an even faster way of tracking if they were to win the competition. Reva noticed that since it was late evening, the lights were on in all the classrooms. Also, all the classrooms windows were visible from the school grounds. This gave her an idea. She said to Richa, "I'll do the first part - treasure hunt - you keep watching the classroom windows. When I go into any classroom, I'll switch the lights off and on, three times. This will act as a signal for you to know my current location. When you do the second part - tracking - come directly to the last classroom from which I gave you the signal." "That's a great idea", said Richa, "I need not go to any of the other classrooms to follow your trail, so we can save some time and finish faster than the boys. Also, switching the lights off and on three times will be a clear signal. It will work even if someone else accidentally switches off the lights in other classrooms. We are going to win!" Do you think they beat the boys?

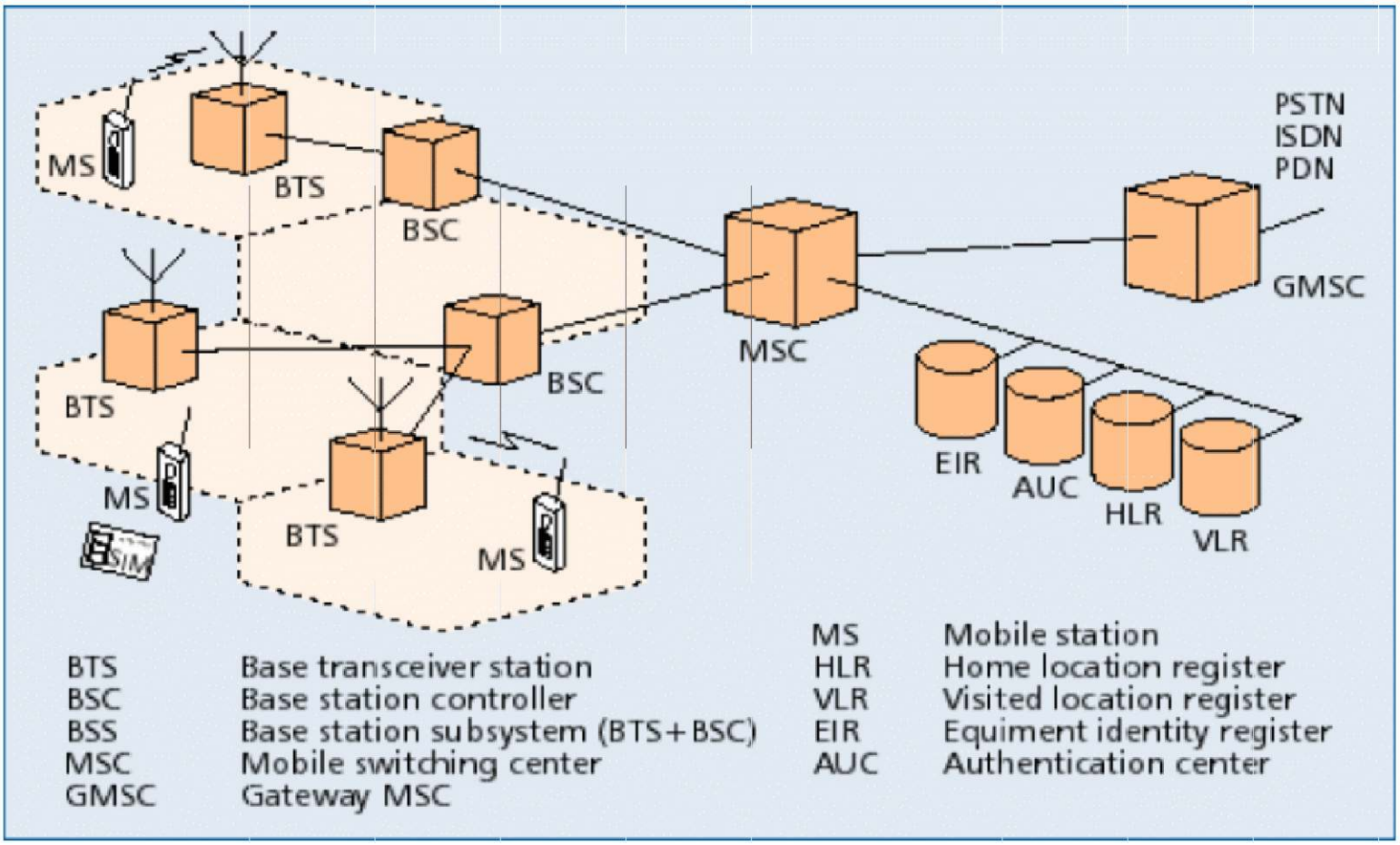
Interestingly, similar principles are followed in a mobile phone network. For example, you may switch on your mobile phone at home, go to a movie and then to a restaurant.
Now when someone calls your number, how does the network know what is your current location?



Just as the postal address system divides a city into various suburbs and areas, each mobile phone network also divides the city into many small areas called Cells. In fact, this is why a mobile phone is also called a cell phone! Each cell has a transmitter called a Base Station, which can often be seen mounted on top of tall buildings. All the Base Stations are connected to a central computer called the Mobile Switching Center (MSC) and this forms the network. For the mobiles that normally operate in that city, this is known as the Home Network. Now, there is a computer called the Home Location Register (HLR), which stores various details about each mobile in that network. The HLR keeps track of the current location of the mobile. Whenever the mobile moves from one cell to another, it informs the HLR about its new location, using a mechanism called signalling. So, when a new call or message arrives for a mobile, it first goes to the Mobile Switching Center (MSC).
The MSC looks up the information in the HLR, to find the current location (cell) of the mobile. The MSC then contacts the Base Station corresponding to that cell, to forward the call or message to the mobile.

In our story, each classroom can be thought of as a cell, and the light as its Base Station. Reva, moving from cell to cell, corresponds to a mobile phone. Richa, keeping track of which cell Reva is currently in, corresponds to the HLR. Switching the lights off and on can be thought of as the signalling mechanism between the mobile and the HLR.

Now what happens when a visitor carrying a mobile enters the city? The ability to use your mobile phone outside your Home Network, such as when traveling, is called Roaming. In order to support roaming, each mobile phone network has a computer called the Visitor Location Register (VLR). The VLR stores various details about mobiles that are currently in the area but are visiting from other networks. When a visiting mobile moves from one cell to another, it first informs the VLR about its new location. The VLR in turn informs the HLR of the visitor's Home Network. Now when a new call (or



message) for the mobile arrives, the MSC in the Home Network looks up the HLR and finds that the mobile is roaming. It then contacts the appropriate VLR to locate the current cell of the mobile and forwards the call.

While this may sound simple, there a lot of intricacies. A city may have several mobile phone networks, each setup by a different operator such as Orange, AirTel, Idea, Reliance etc. Roaming is often made possible by agreements between these mobile network operators. Roaming has several interesting aspects which we will see in a later article.

For example, suppose you are roaming in Delhi with a mobile registered in Mumbai. Now if you use the mobile to call and speak for five minutes with one friend in Mumbai and another friend in Delhi, which call will cost more? So the next time you make a call on your mobile, try to figure out what may be happening in the background. It may keep you amused till your call gets through!

MSC: Mobile Switching Center is the central entity in a mobile network. It is responsible for carrying out the various steps in making calls to and from a mobile.

HLR: Home Location Register is a database of mobile user information. It is a key component of mobile networks and contains information such as account status, user preferences, features subscribed by the user, current location etc.

VLR: Visitor Location Register is a database, similar to a HLR. It is used by the mobile network to temporarily hold information about roaming users (users outside their home area).

Some interesting related websites are:

http://www.privateline.com/PCS/structure.html
http://www.mobilein.com/mobile_basics.htm
http://electronics.howstuffworks.com/cell-phone.htm

Illustrations: Mrs. Kaumudi Sahasrabudhe