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Sprint® Corporation

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1 Company Overview

Sprint® is a major 4G LTE telecom operator in United States. Their customer base is close to 30 million in United States. Sprint® has very wide spectrum throughout US which gives customers very good quality of service.

1.1 Mission

Sprint® strives to get better every day. They believe that communication brings people together and helps them stay connected.

1.2 Values

Aligned with mission Sprint® has outlined following are their values:

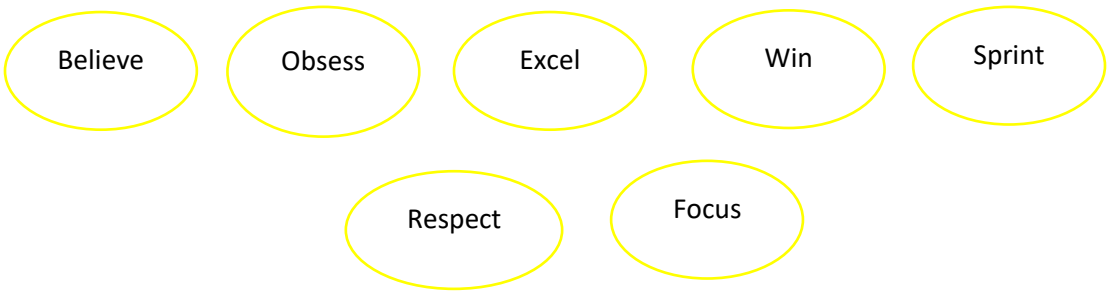

Figure 1 Sprint® Values

1.3 Vision

Sprint® recently emerged as one of iconic brand because of their continues effort to get better every day. Consumers has rate Sprint® as best mobile platform in America and they recommend people to switch into Sprint®. Sprint® achieved this by providing world class products with competitive price and highest customer satisfaction.

1.4 Strategy

To get better every day Sprint® has led below strategy:

Figure 2 Sprint® Strategy

2 Products/Services

Sprint® offers 4G LTE data service to its customers as specified by 3GPP standards. For any wireless communication backhaul is most the key factor. Major backhaul type in Sprint® is fiber optic cable which helps customer experience high speed mobile internet. Sprint® has partnered with major smartphone manufacturers (Apple, Samsung, etc.) so that customer does not have to but expensive smartphones. Sprint® Store has expert customer representatives where you can walk-in and walk-out with smartphone in your palm. Its state of the art 4G LTE coverage map and Voice is as follows:

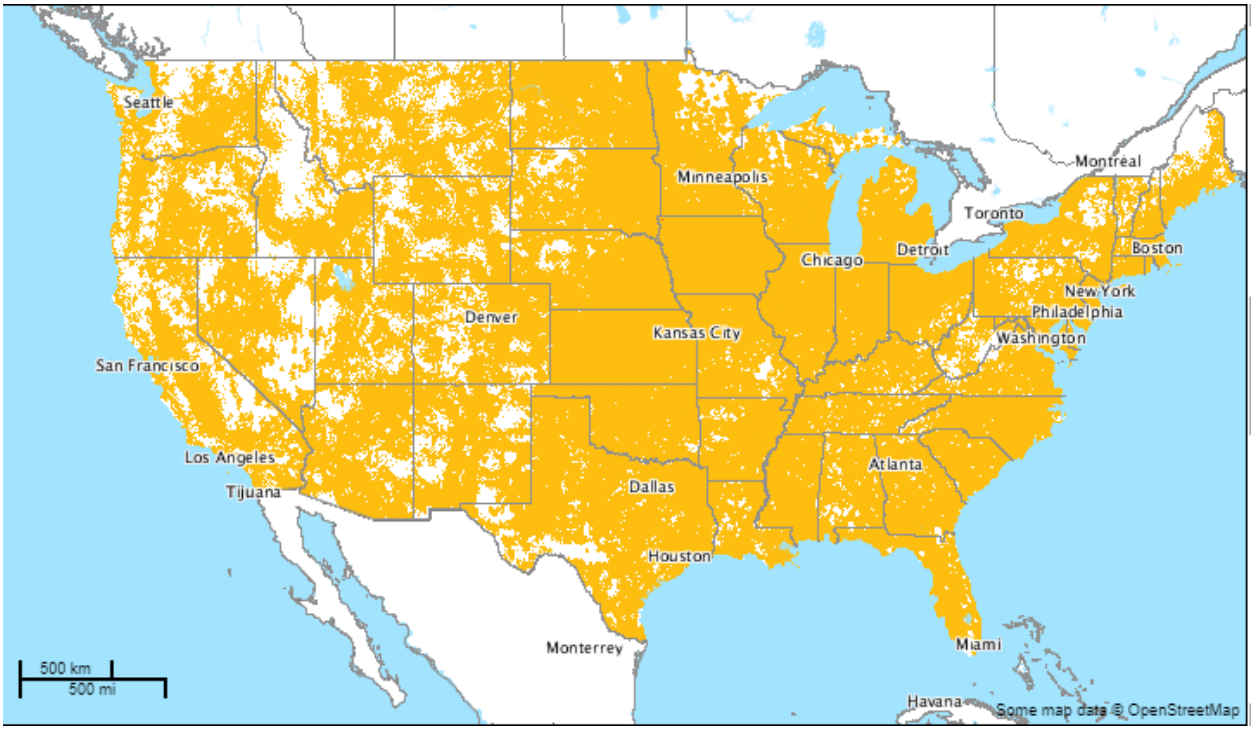

Figure 3 4G LTE Coverage Map

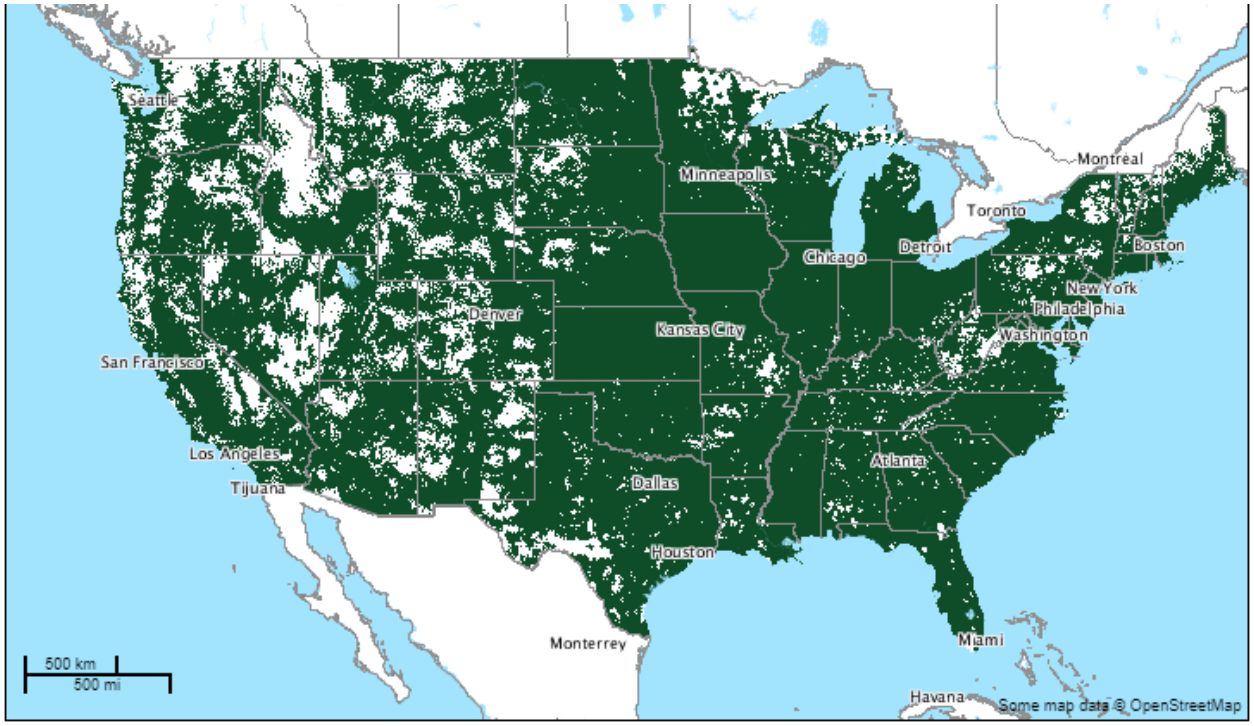

Figure 4 Voice Coverage

2.1 Future Plans

Sprint® plans to integrate existing voice network with LTE known as Voice over LTE(VoLTE). Their existing voice network is 3G dependent which has some compatibility issues if new customer is coming into Sprint® from other operator.

3 Major Competitors

AT&T®, Verizon®, T-Mobile® are top competitors for Sprint®. Sprint®'s customer base is lower compared to all other operators. However, Sprint® has very wide unutilized radio frequency band. This will allow Sprint® to add many customers without having to augment existing infrastructure or invest money.

In addition to wide band availability Sprint® is also offering very competitive price for services. This is drawing more customer away from other telecom operators. In fact, Sprint® has proven with statistical data that people are paying almost twice for same quality of service with another telecom operator. Hence, more people are switching to Sprint®.

4 Team - Coverage Throughput and Network Analysis

I was involved with above team which is responsible for maintaining highest throughput for whole United States. National Radio Frequency (RF) Planning was parent team under which we were reporting to. My team's major responsibility was to keep monitoring existing LTE network and troubleshoot in case of any issues.

We used Atoll® tool which helps predict results and simulate bug in real time environment. Atoll is used by many telecom operators for RF Planning and Optimization.

Our team was also handed responsibility to model Magic Box (Magic Box will be explained subsequently) in Atoll. My job was to help my team prepare raw data which was required for importing Magic Box into Atoll.

5 Magic Box Automation Project

Sprint® recently launched product known as Magic Box. Purpose of Magic Box is to provide better network coverage in areas where cell towers are expensive to place and requires sizable chunk of money. Magic Box has in-built RF optimization mechanism which relays attenuated signal from cell tower and acts as cell tower when placed in apartment building.

Magic Box is very easy Plug N Play device which does not require any installation or manual intervention. With help of one use case Sprint® team has demonstrated that speed of download/upload was improved to 54 Mbps from 15 Mbps. My job was to help prepare raw data as follows:

- Resolve GPS Inaccuracy
- Identify Correct Building
- Identify correct wall facing of Building
- Calculate Azimuth Angle with respect to Cell Tower
- Define Projection onto clutter heights and automate height extraction

These job roles will be elaborate in detail subsequently.

6 Network Engineering Intern

Working as Network Engineering Intern, I used ArcGIS for Desktop 10.5.1 for performing tasks assigned. Major tasks with which I worked with are as follows:

1. **Magic Box Height with respect to Nearest Ground Surface:**

   ➔ Magic Box as explained above ideally was kept near wall of building to provide coverage to maximum area. It can be on 2nd floor of building or 3rdor 4th and so on. My job was to calculate this height based on ground floor.

   ➔ Height was provided by Magic Box along with GPS co-ordinates. However, this height is called as GPS Height. We wanted to extract Height with respect to nearest ground surface.

   ➔ Orthometric Height which can be roughly approximated as Mean Sea Level (MSL) needed to be calculated. Below Figure 5 will help us understand this

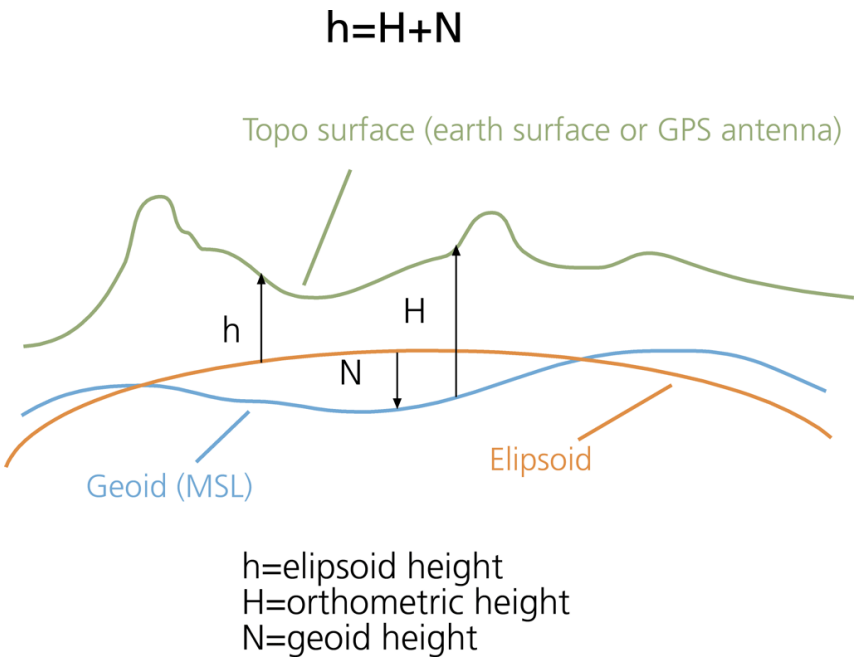

Figure 5 Different Heights and association between them

- ➔ In above Figure 5 my job was to calculate H with respect to h and N. h called as Ellipsoid Height is nothing but GPS Height. N called as Geoid Height is height of MSL with regards to gravity of earth.
- ➔ In above Figure 5 ellipsoid height is closest approximation of earth surface as earth surface is very rough and uneven. Geoid height N is variation of sea level for different geographic locations. For e.g., MSL for Chicago can be assumed as 0 and MSL for Miami can also be assumed as 0. However, reference 0 point for these 2 locations is not 0.
- ➔ Gravitational force which is little different for various location is primary reason for MSL being different. We know value of Geoid Height at a location based on its GPS location.
- ➔ Combining this I used this information to calculate MSL for Magic Box and then cross referenced it with height of building to calculate height of Magic Box.

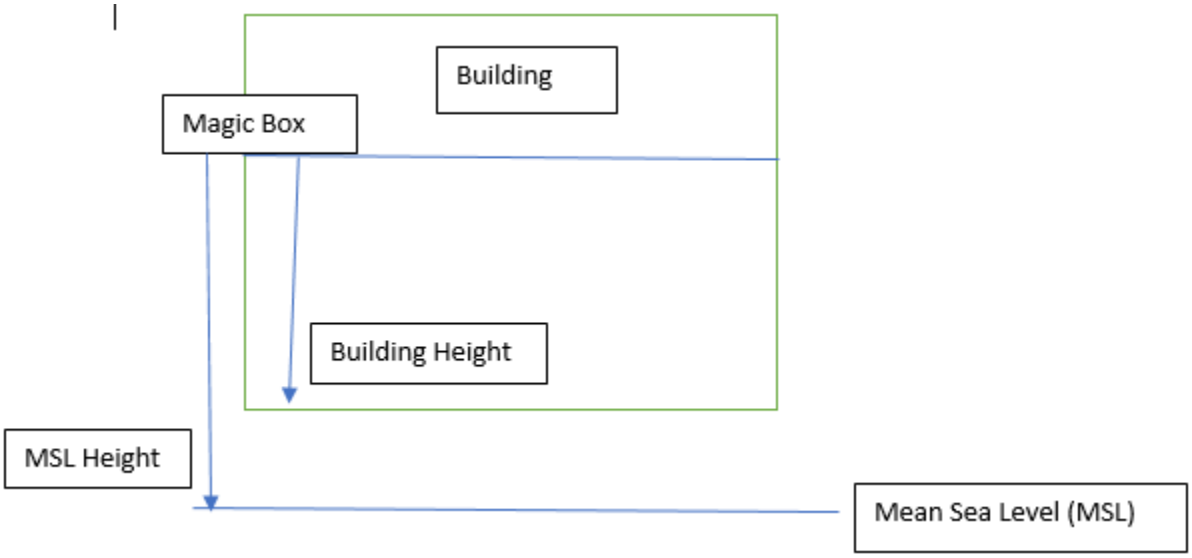

Figure 6 Magic Box Height Calculation

2. Calculating Building Height based BIL Raster Dataset:

➔ Sprint® has set of BIL dataset which contained height of building. It is called as Clutter Height in this context.

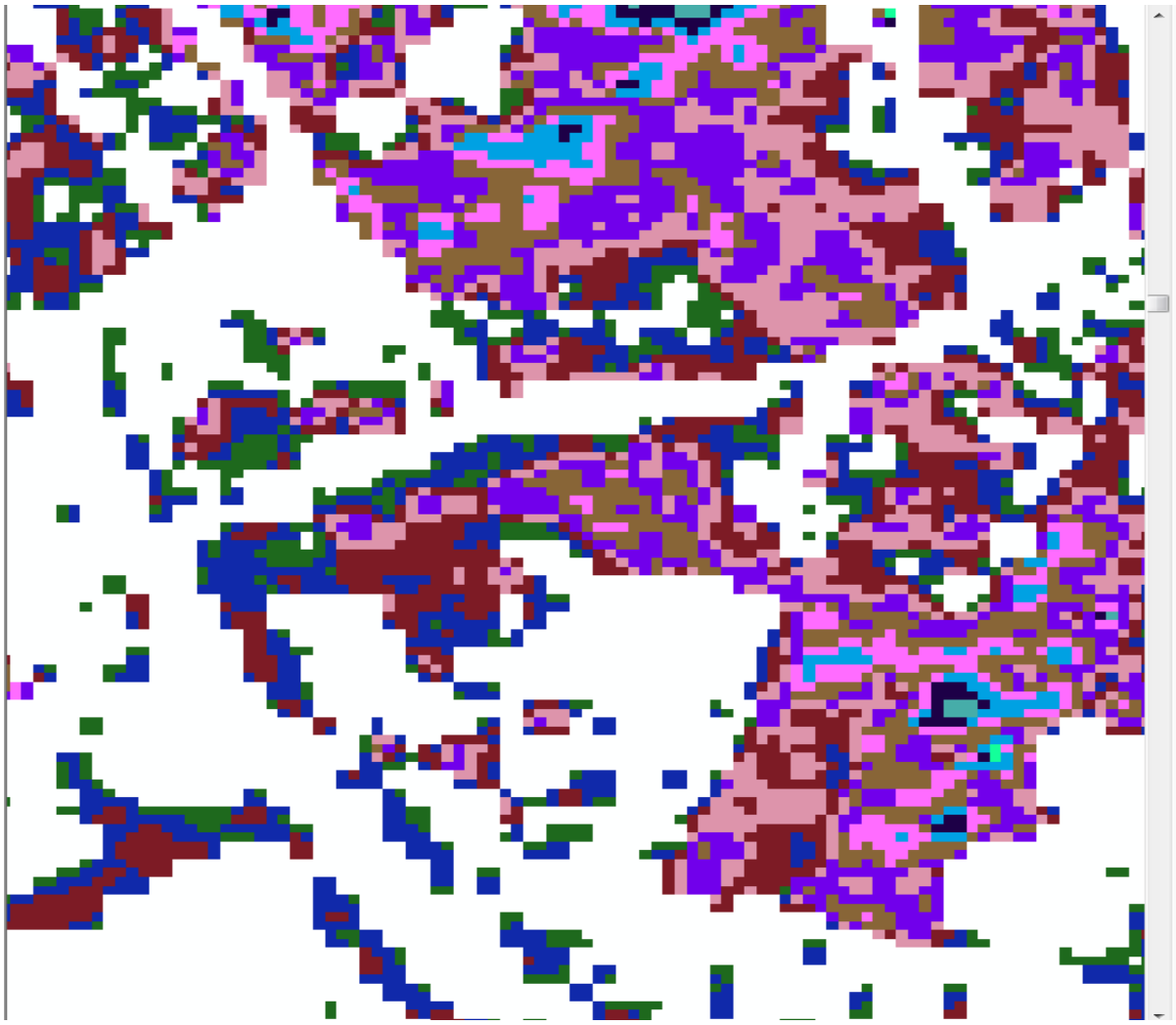

Figure 7 ***Clutter Heights symbolized as Unique Values in ESRI***

➔ I had to use appropriate projection on this raster in first step. For e.g., for Chicago metropolitan area I used Projected Co-ordinate System (EPSG: 32616) with WGS 84 as Geographical Co-ordinate System at back-end. These heights were collected according to pre-defined markets.

- ➔ Later I combined different building polygons available from sources such as Open Street Map, Skyline, Atoll Geodata Polygons in ESRI. Output data format was ESRI shapefile.
- ➔ Next step was to define same projection as used with BIL dataset with polygon shapefile.
- ➔ Then I overlaid this shapefile on top of BIL dataset from which height had to be extracted. I used **Zonal Statistics as a Table tool from Spatial Analyst toolset in ESRI** to extract height. **MAXIMUM was stat operation I used**. Other available options were MINIMUM, MEAN, VARIETY, etc.
- ➔ When we are working with separate set of data (in this case shapefile is vector dataset and BIL is raster dataset) with Zonal Stat, ESRI internally converts our shapefile into raster. For this, we need to specify zone attribute. I used **polygon id as Zonal attribute** in my case.
- ➔ In some cases, raster dataset (spatial resolution of dataset was 10mX10m) was very big. Hence it had to be broken down in little small fragments. However, zonal stat at a time runs on a single raster. Hence, it had to be mosaicked into a single raster. Further, I used raster compression with **L277(lossless compression)** to compress huge data in form of jp2 format.
- ➔ I used **Iterate Raster in ModelBuilder** to mosaic raster's in addition to the tools mentioned above to automate process for rest of markets.
- ➔ Using Input Path of raster and Spatial Reference(projection) as a parameter, it was further simplified and automated.

3. **Move Magic Box to a correct location inside building polygon**

➔ GPS location reported by Magic Box when plotted on map sometimes had little inaccuracy. For e.g., Consider an example of one MB location in Chicago.

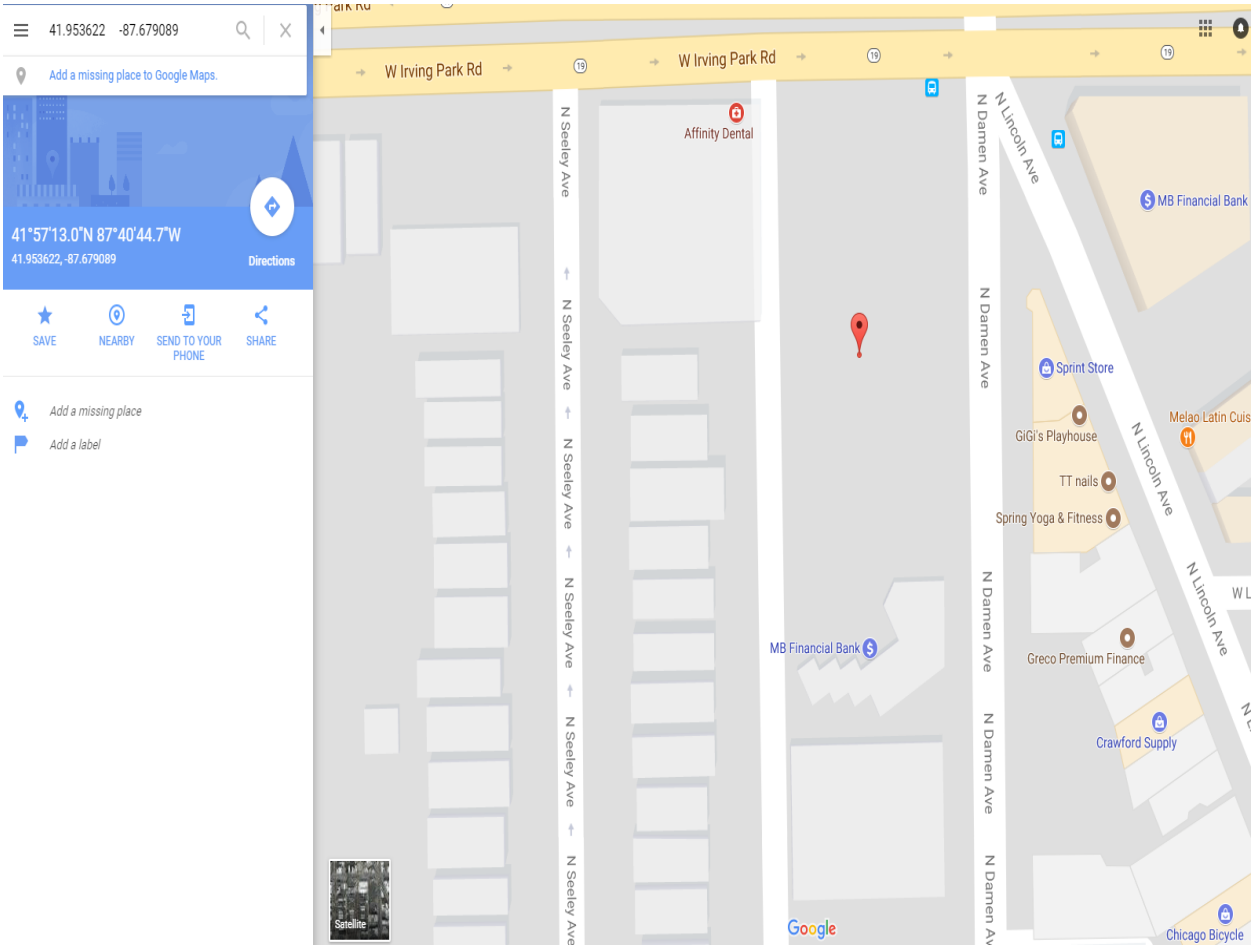

Figure 8 Inaccurate GPS location

➔ Dropped pin is Magic Box location which is supposed to be inside polygon labelled Sprint® Store. Because of GPS error, it is placed on street.

➔ My job was to determine correct building polygon as well as correct wall of building.

➔ Since we had to move Magic Box to correct wall of building, we tried to move around this and predict attenuation and gain values in Atoll for reference and came to

conclusion that it had minimal impact provided floor of building is correct. Hence, we decided **to use Midpoint of wall as probable location.**

➔ Overall process was broken down into several steps as explained below:

1. Collect building polygon and display them, plot all Magic Box locations on Basemap.

   Polygon to Line (Data Management Tools): Building Polygon

2. Then I split edge of polygon as a line at vertices.

   Split line at Vertices (Data Management Tools): Getting edge of Polygon as a line

3. Then I calculated mid-point of this edge

   Feature Vertices to Points (Data Management Tools): MID Operation for lines generated in above steps)

4. Next step was to add X, Y co-ordinate or LAT, LONG values in attribute table of mid-points generated in above step

   Add XY Co-ordinates (Data Management Tools): with respect to WGS 84 co-ordinate system

5. Next step was to Generate Near Table for these mid-points with respect to cell-tower connected to Magic Box. In ESRI Near Distance and Near Angle is calculated based on below logic:

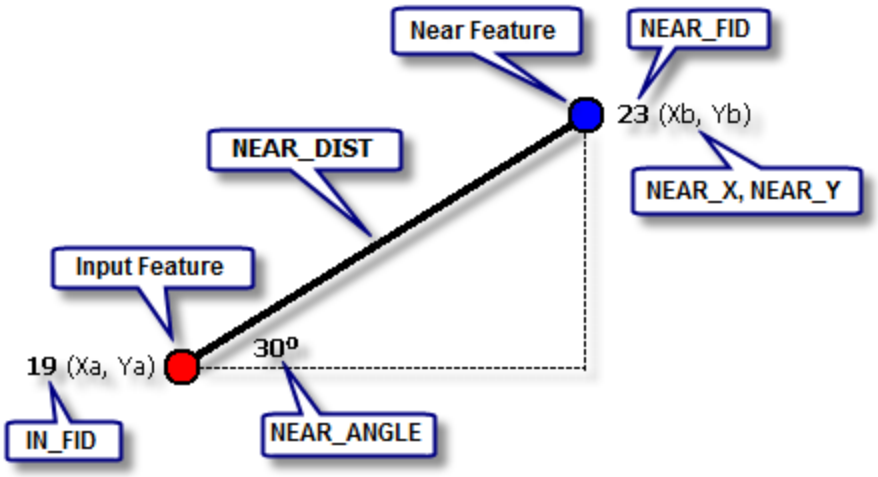

Figure 9 Near Angle and Distance Calculation

6. Near Angle had to be converted into Azimuth for our application. This was done based on below formula:

```
import arcpy

# Near tool does not calculate angle in azimuths
# This script, using the output of the tool, converts the angles
# to azimuth angles.

in_table = r"C:/data/city.gdb/near_table"

angles = arcpy.da.SearchCursor(in_table, ["NEAR_ANGLE"])

azimuth_angles = []

with angles as rows:
    for row in rows:
        angle = row[0]
        if angle <= 180 and angle > 90:
            azimuth_angles.append(360.0 - (angle - 90))
        else:
            azimuth_angles.append(abs(angle - 90))
```

Figure 10 Standalone Python Script to calculate Azimuth

7. Azimuth can be understood with help of below diagram:

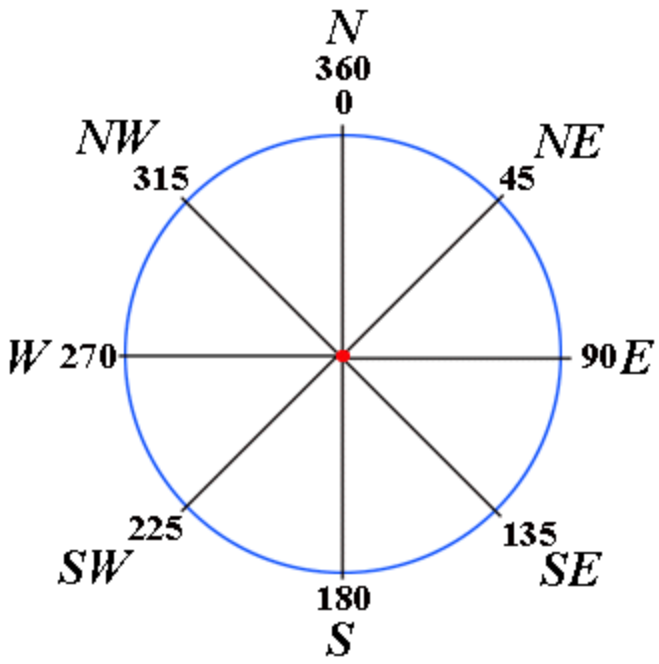

Figure 11 Azimuth explained

8. Next step was to know which cell tower was linked with Magic Box along with Azimuth. This was mapped against all mid-points calculated and then best approximate was selected amongst them. Offset used was 7.5.
9. To eliminate points which fall under different polygon, I used Identity tool in ESRI to add Polygon Id. This helped in identifying points to skip for processing.
10. Steps 1 to 9 mentioned above was automated using ArcGIS ModelBuilder with addition of Python wherever necessary.

Summary

- One of problem which I faced while working as an Intern in Sprint®, was to devise a detailed approach towards finding best possible location on map for Magic Box.
- Even after approach was finalized, we had to perform several join on tables to integrate scattered data. This was solely based on OID and FID (created internally by ESRI)
- I addressed this issue by **using ModelBuilder in ESRI to perform these repetitive and complicated tasks with parameterized methodology**.
- Most important outcome from this internship which I would like to mention is that I was able to apply GIS concepts learned in school to practical field of telecom. From this point onwards, I have a clear understanding of how to solve problem statement from applied GIS standpoint; how we do we find perfect tool in ESRI ArcGIS to solve our issue.
- This internship helped me develop research mindset. In other words, **I can think what's happening behind scene when I use any of ready-to-use ArcGIS tools.** I would like mentioned this as single most skill I learned from internship.
- In addition to GIS skills learned, applied, I also managed to get fundamental knowledge of Long Term Evolution (LTE) technology. What is LTE, how does it work? Why do we need LTE? etc.
- Considering time frame, some of automated processes such as Web Service Implementation along with integration ArcGIS Server is something which I could have implemented. It would have involved some research with database architecture of Atoll. Nevertheless, my summer internship was excellent and I shall highly recommend my fellow colleagues to pursue this opportunity if presented.