Android Signal Mapping Guide

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STEP-BY-STEP GUIDE: MORNING AND EVENING

Please follow these steps every morning to prepare your measuring environments, and every evening to close up your environments.

Every Morning (Before Daily Measurement)

1. Initialize the phone
   a. Turn on the phone.
   b. Ensure that the phone has a full charge. If not, begin charging the phone immediately.
2. Make sure that location services are on[1]
   a. Navigate to "Settings"
   b. Scroll down to Location
   c. Make sure that the Location switch is set to on
3. Set up Camera location tag
   a. Open up the Camera by tapping on the camera app
   b. On the Screen, open up the settings by tapping on the gear icon (by default it is in the upper left of the screen)
   c. Scroll down to "Location Tag" and make sure that it is set to on.
4. Set up NetMonitorLite
   a. Open the app by tapping on the NetMonitorLite Icon:

   b. On the home screen (MAIN tab), tap the red circle icon in the upper right corner of the screen.
   c. The red circle will turn into a white square.
   d. The app is now active. Tap the Home screen button to exit the app view.
5. Set up WiGLE WiFi
   a. Make sure that the cell phone's WiFi is activated. If not, make sure to turn it on.
   b. Open the app by tapping on the WiGLE WiFi Icon:

   c. On the home screen, tap the grey X that is in the upper right section of the screen.
   d. This X will turn into a WiFi icon, with an oscillating measuring arm.
   e. The app is now active. Tap the Home screen button to exit the app view.
6. Set up Cell Map
   a. If the phone has data/internet availability, make sure that it is turned on, as this will allow the app to automatically geo-tag the detected cell towers. Otherwise, I can do it separately.

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[1] Here's a better guide, with pictures: http://visihow.com/Use_Location_Services_on_Galaxy_S5

b. Open the app by tapping on the Cell Map Icon:

c. The app is now searching for Cell Towers

7. Prepare for safe stowing:
   a. Turn off the cell phone screen by pressing the power button on the side of the phone (the other button on the side of the phone has two levers for volume control. The power button is the one that is alone).
8. Stow the phone in a safe place for transport
   a. Put the phone in a backpack
   b. Try to limit how much you jostle the pack during the day
   c. Monitor them from time to time, and make sure that battery levels remain acceptable (>50%), and that the apps are still running.

Every Evening (After Daily Measurement)

Here I will walk through the daily steps of post-data collection. Roughly, this centers around "export" and "extract" of data:

Export: Convert the data that the app has collected into a human-readable format, e.g. *.csv or *.kml

Extract: Move the data from the phone to either the cloud (e.g. Google Drive), transmit via Email, or to your computer's local file system.

1. Organize your phones based on what they were measuring (i.e. which apps were running) so you know what app data to be looking for.
2. One by one, deactivate the recording of each app(if necessary), and then export and extract the collected data from each phone. Please refer to each app's individual section for "Data Export and Extraction" for the exact directions on how to do this:
   a. NetMonitorLite Export and Extract: https://docs.google.com/document/d/1ZzY5xwKL7c_jTwZAtOB4dEQkPnmN9w11IQWtj0yDbdM/edit#heading=h.ofzdcatgc6ws
   b. WiGLE WiFi Export and Extract:https://docs.google.com/document/d/1ZzY5xwKL7c_jTwZAtOB4dEQkPnmN9w11IQWtj0yDbdM/edit#heading=h.uprrt1i8cbff
   c. Cell Map Export and Extract: https://docs.google.com/document/d/1ZzY5xwKL7c_jTwZAtOB4dEQkPnmN9w11IQWtj0yDbdM/edit#heading=h.ssaelgz9e38f
3. Once the data has been exported and extracted (*IMPORTANT: VERIFY THAT THE DATA IS SAFE BEFORE YOU PROCEED), you may clear the phones of the current app data to prepare for the next day's session. Although given the storage capacity of these phones nowadays, this may not be necessary. However, for certain apps, I do recommend you clear the data at the end of each session (which ones I recommend

noted below, and why). Please refer to each app's individual section for "Clearing App Data" for the exact directions on how to do this (*under construction)

    a. NetMonitorLite Data Clearing: I do NOT recommend that you clear the app data at the end of each session. Since the app maintains the data from each separate sessions within the phone, so it keeps recording sessions separate in a clear manner for future manipulation.

        i. Clearing the app data: https://docs.google.com/document/d/1ZzY5xwKL7c_jTwZAtOB4dEQkPn mN9w11IQWtj0yDbdM/edit#heading=h.k0ylwmyi64ue

    b. WiGLE WiFi Data Clearing: I DO recommend that you clear the app data at the end of each session, but also back it up before you do this each time (which is quite easy). I recommend this because WiGLE WiFi doesn't clearly consolidate each individual recording session, and so will keep each exported/extracted data set clean.

        i. Clearing the app data: https://docs.google.com/document/d/1ZzY5xwKL7c_jTwZAtOB4dEQkPn mN9w11IQWtj0yDbdM/edit#heading=h.n5k56ajgac4i

    c. Cell Map Data Clearing: I DO recommend that you clear the app data at the end of each session. Although this app does not require much space at all since it's only recording the noticed cells (and not taking records at pre-defined sampling intervals like WiGLE or NML), it does not cleanly consolidate each run into separate sessions, so this will keep each exported/extracted data set clean.

        i. `Clearing the app data: https://docs.google.com/document/d/1ZzY5xwKL7c_jTwZAtOB4dEQkPn mN9w11IQWtj0yDbdM/edit#heading=h.3r9ocdhphcdx

4. Now that data has been exported, extracted, verified, and when necessary local data has been cleared from the apps, shut down each phone, and charge them overnight.

ANDROID ENVIRONMENT CONFIGURATION

Essential Hardware/Software

To move data between the your Android device and your local laptop, you will need either a) a Micro-USB cable, or b) an internet/WiFi connection. Additional options include a MicroSD card transfer or Bluetooth File Transfer, but these are not covered in depth here (because I don't have either available to me unfortunately).

Essential Utility App: ES File Explorer

This app allows you to manage your Android Device's internal file management system. This is important because it will allow you to navigate to your data within the phone.
You can install it from the Google Play Store at
https://play.google.com/store/apps/details?id=com.estrongs.android.pop.
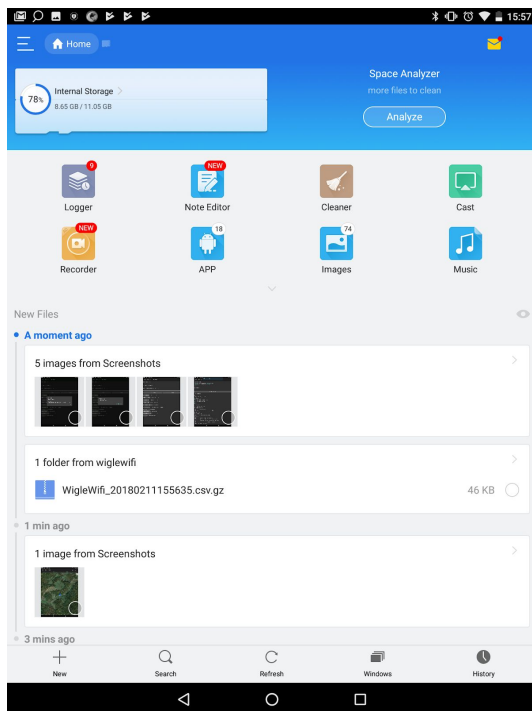
To navigate to the local file view within ES, tap the three bar settings options icon in the upper left of the "Home" screen. This will open a drop down menu:
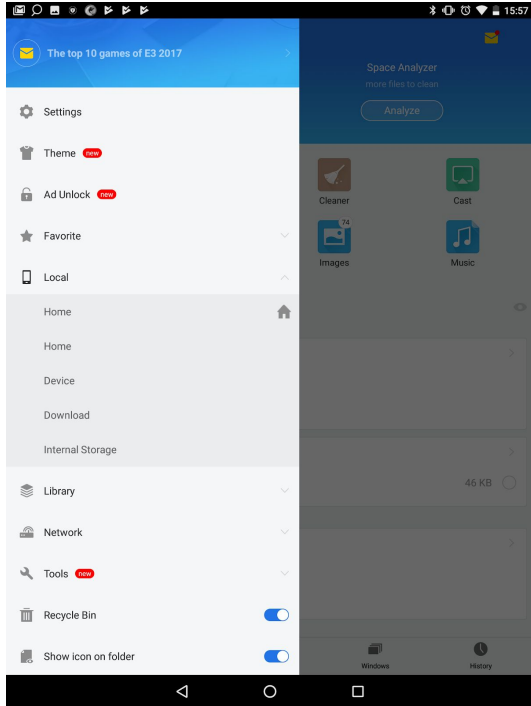
In this menu, you will see two "Home" options. Select the second one (the one without the house icon on the left). This will take you to the ES Local File View:

You can do almost all of your file navigation from this screen.

Installing Android Apps without the Google Play Store

For one reason or another, certain apps may not appear in the Google Play Store, possibly due to the device restrictions put in place by Google or the app developers. This however does not mean that it is impossible to install the app on your phone. You just have to do it manually.
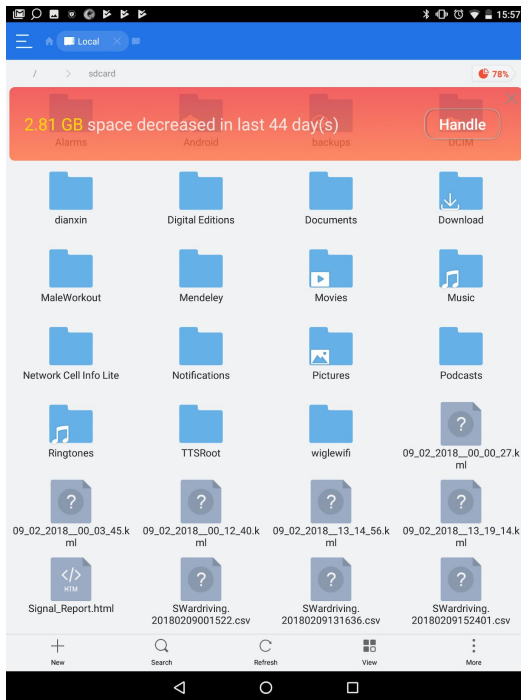
Fortunately, this is fairly simple to do: each Android App is installed in the form of an *.apk file. If you can get an app's APK file, then it can be manually installed on the phone. For this project, I have begun placing stable APK files of the apps we will be using in the "Uganda" shared Google Drive directory. To get the .apk file for an app via Google Drive:

1. Open Google Drive on your phone
2. Navigate to the "Android APKs" directory (I created) in the shared Uganda directory
3. Download whichever APK you want on your phone

You can also get the APK file onto your phone with a MicroUSB cord:

1. Connect the phone to your computer
2. Once your phone is recognized by your computer, drag and drop the APK file you wish to install into your phone's local file system

Before you install, you will need to ensure that your phone has the requisite permission to install software from "unknown sources". To do this:

1. Navigate in your phone to "Settings" -> "Security".
2. Scroll down to "Unknown Sources"
3. Select the box/slider to "Allow installation of apps from unknown sources"

You are now ready to install the app via apk:

1. Navigate in your phone's local file system via ES File Explorer to the downloaded APK -OR- follow the phone's active dialog system (via swipe down from top of screen) to select the APK (it's likely in "Downloads")
2. Once you select the APK, the phone will allow you to attempt to install it.
3. Once installed, it may ask you to set its permissions (a process that is usually done during the "normal" installation in the Google Play Store). Follow the link the app tells you to and adjust its permission setting as you see fit.

At this point, your app should be good to go!

CRUCIAL NAMING CONVENTIONS

For clarity's sake, please use the following naming convention on your files when exporting. This will help us keep our workflow organized, especially when dealing with many files from many phones.

NetMonitorLite (Cellular Monitoring)

Format: cellular_nml_<mmddyy>_<carrier>_<generation>_<location>.<file extension>
Example: cellular_nml_030318_orange_3g_kakuma.csv

Wigle Wifi (Wifi Monitoring)

Format: wifmap_wigle_<mmddyy>_<location>.<file extension>
Example: wifimap_wigle_030818_kakuma.csv

Cell Map (Cell Tower Locator)

Format: ct_cellmap_<mmddyy>_<location>.<file extension>
Example: ct_cellmap_030418_kakuma.csv

FILE EXTRACTION METHODS

Once you have your data exported and/or readily available for extraction from your phone, you can follow any of these three methods to move them to your computer.

Via Micro-USB Cable

Requirements: Micro-USB cable; Computer w/ USB port.
1. Connect your phone to the computer with the Micro-USB cable
2. Once your phone becomes accessible to the computer, navigate to the location of the file you'd like to extract.
3. Either copy or cut the file out of your phone's internal file system.
4. Paste that file into your computer's local file system

Frequently Asked Questions:
- *Q: I don't see my new files that are on my phone on the window view on my computer.*
    - The computer-android connection via cable does not update quickly, so even if files are ready for extraction, they may not appear in your computer's view of the phone's files. Do not worry, your file is safe, but this is a known problem with Android phones. You can either a) wait for the update when this occurs, or b) reboot the phone to force the update.
- *Q: I connect my phone to my computer, and can see it charging, but I can't find my phone on my computer*.
    - The default connection setting when you connect your phone to your computer is to charge only. If you connect your phone and you see this situation, swipe down from the upper left corner of the screen and you should see an option that says something along the lines of "USB connection for charging only". Tap that option and you'll be presented with a pop-up dialog that you can use to adjust the wired connection setting. Enable file transfer through this dialog, and your computer should now see your phone connected.

Via Email/Cloud Upload

Requirements: Cellular data signal or Wireless Internet Connection.
1. Open the ES File Explorer App
2. Navigate to the file you wish to upload/send via email:
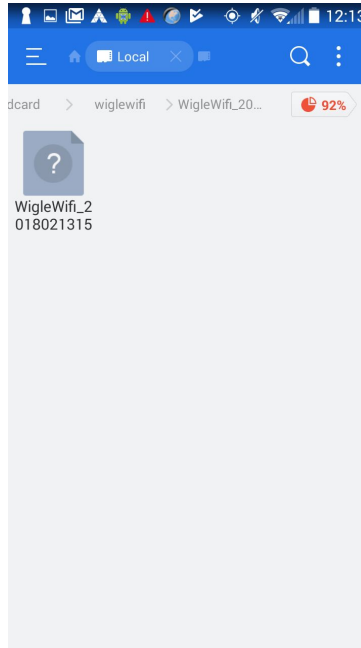
3. Once you have found the file, hold your finger down on the file until an orange checkbox appears in the lower right corner of the icon, and an additional menu appears at the bottom of the screen:
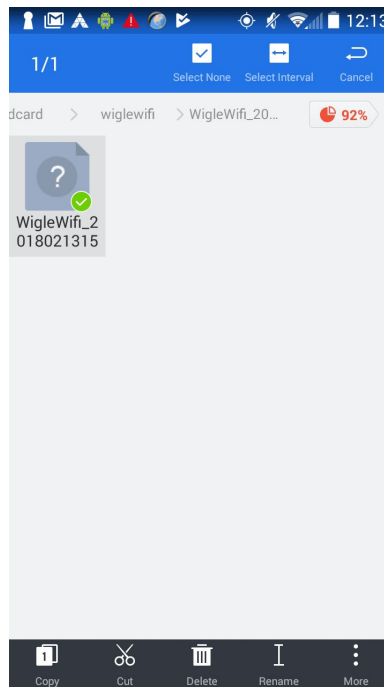
4. If you would like to send multiple files in this directory, you can now tap on them as well and this will select multiple files.
5. On the menu at the bottom, select "More" and a pop up dialog options menu will appear:
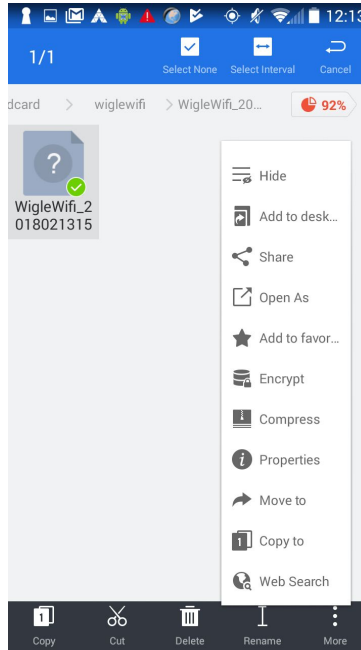
6. On this menu, select "Share". This will pop up another dialog window that gives you the file sharing options:
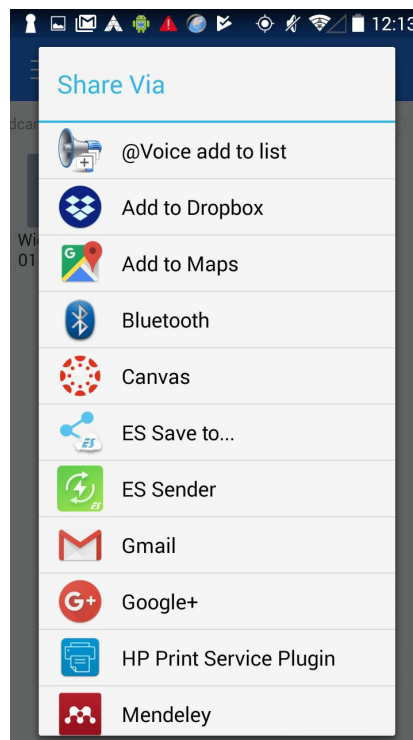
7. From here, you can select either Gmail (left) or Drive (right), among other options:
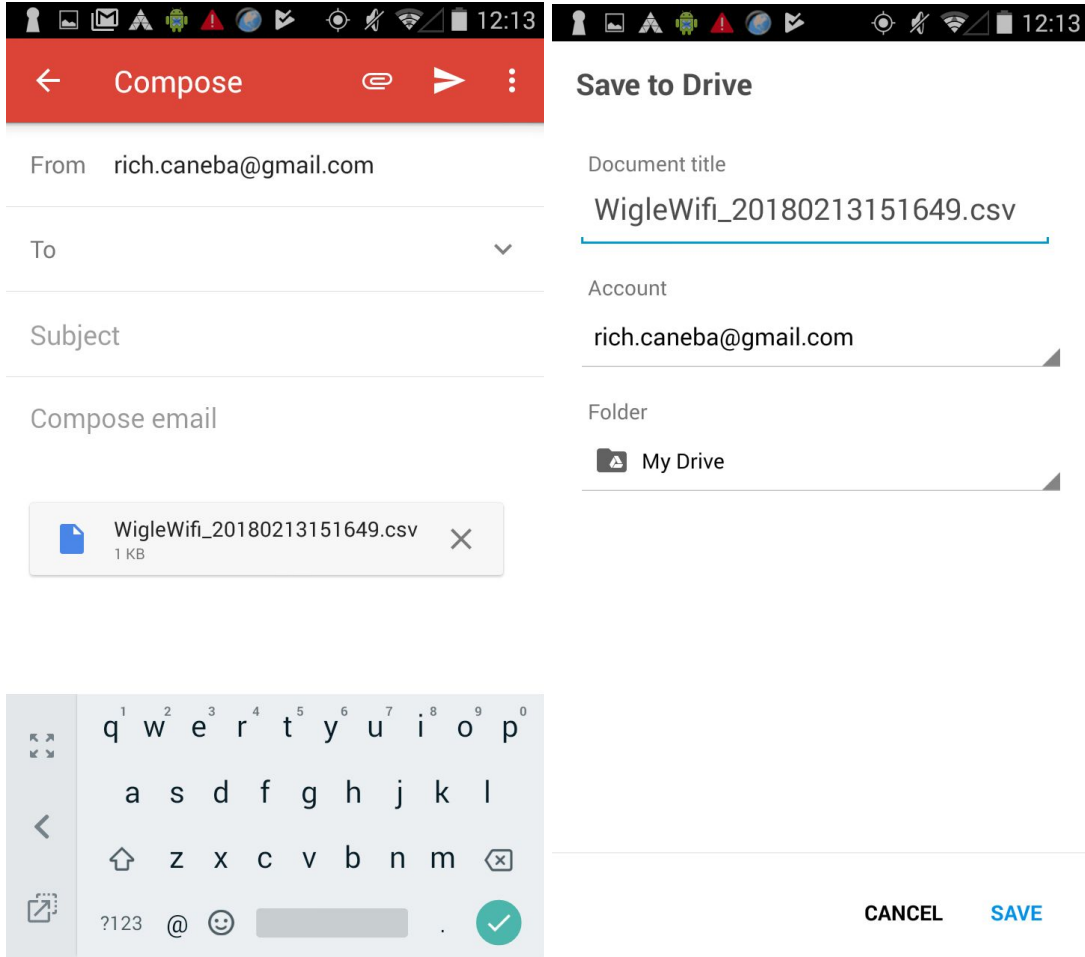
8. Either send the message, or complete the upload, and you or someone can retrieve the file once it's finished transmission.

Via MicroSD Card

Requirements: Your phone must have a MicroSD card that can be removed from the phone; MicroSD Card Adapter (SD Card size adapter that you can insert the MicroSD card into); a laptop with an SD card slot, or a USB SD card dongle.

Via Bluetooth File Transfer System

Requirements: Your phone must be capable of Bluetooth Connectivity (most data phones are capable of this); Your Laptop must either be capable of receiving files via Bluetooth, or have a Bluetooth dongle (likely through USB).

GEO-TAGGED PHOTOS

These steps will walk you through how to take geo-tagged photos with your Samsung Galaxy S5. It's quite simple, and will allow me to generate maps based with your photos. So for instance, if you take photos of cellular towers, I can generate a map that is based on the location of these photographs.

Setting up your phone to geotag photos

1. Open up the Camera app on your phone by tapping on the Camera app icon
2. On the Screen, open up the settings by tapping on the gear icon (by default it is in the upper left of the screen)
3. Scroll down to "Location Tag" and make sure that it is set to on.

At this point, photos you take should have a geotag, which by default includes latitude, longitude, and altitude.

Extracting the Photos from your Phone

The default location of the photos should be in:

/DCIM/Camera/…

Using ES File Explorer, you can email these images to someone, or access via a Micro-USB cord connected to your computer (follow general data extraction protocols defined in this guide).

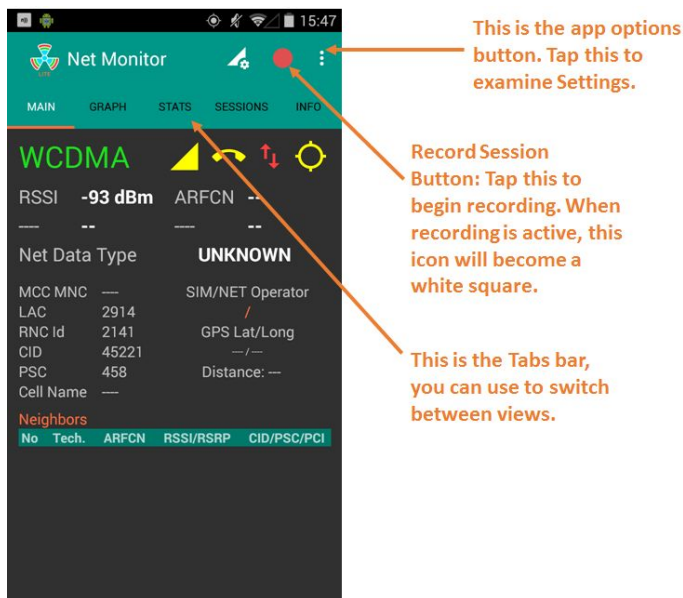# CELLULAR SIGNAL MAPPING VIA NET MONITOR LITE

Purpose of this App

This app is used to detect the presence of cellular signal availability at certain locations. **While this app can detect the presence of cellular signal from the defined carrier for the phone at your location it does not record the location of the actual tower/cell that is being detected, and is the signal's source.** Thus, this app is useful for measuring cellular signal strength, but it does not get the geographic coordinates of the tower/cell that is being measured from.

Installing and Configuring The App

Navigate to the Net Monitor Lite app in the Google PlayStore, and install it on your Android device: https://play.google.com/store/apps/details?id=ru.v_a_v.netmonitor

Once installed, the home screen of the app should look like this:

This is the app options button. Tap this to examine Settings.

Record Session Button: Tap this to begin recording. When recording is active, this icon will become a white square.

This is the Tabs bar, you can use to switch between views.

To configure the Settings, tap on the options button in the upper right of the app home screen (see the figure above for its location), and navigate to the Settings from the drop down menu. Here, you can adjust the app's various options, including saving options, bands naming, and sampling intervals:
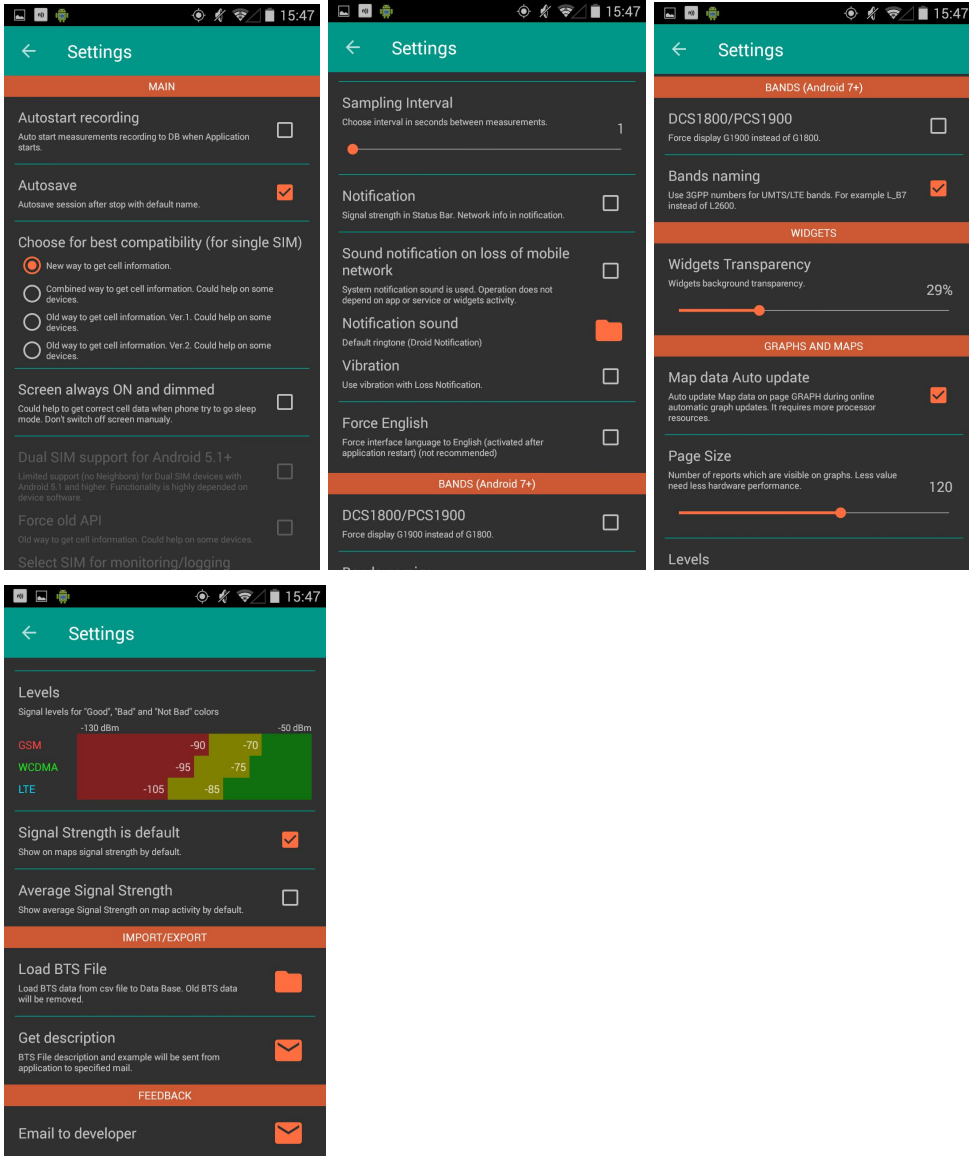
Many of the options can be left in their default setting, but you should:

a) Make sure that "Autosave" is turned ON
b) Make sure that "Screen always ON and dimmed" is OFF
c) Make sure that the "Sampling Interval" is adjusted to whatever you'd like (1 second gives you highly granular data, but you probably don't need data that granular)

You may also set the phone to alert you whenever you lose signal, but this may not be necessary given our purposes.

Data Collection

Once you are ready to begin your data collection, follow these steps:

1. Open up the NetMonitor Lite app

2. Tap the red circle icon in the upper right corner of the "Main" screen to begin recording your session (it will turn into a white square when session recording is active).
3. Turn off the screen display to preserve battery.
4. Stow phone away in safe place, and minimize jostling to avoid accidental termination of session

Once you have completed your recording session, tap the white square in the upper right corner of the "Main" screen to end the session, which will cause it to turn back into the red circle.

At this point, you will want to make sure that the session is clearly labelled within your phone system to ensure that the data source is known once it's time to extract. To do this, follow these steps:
1. Navigate to the "Sessions" screen
2. Here you will see the session you recorded, with the label "Session <N>", where <N> is some integer, depending upon how many sessions you've recorded previously (in this screenshot I've already relabelled a few sessions, but sessions 4 and 2 are still present):
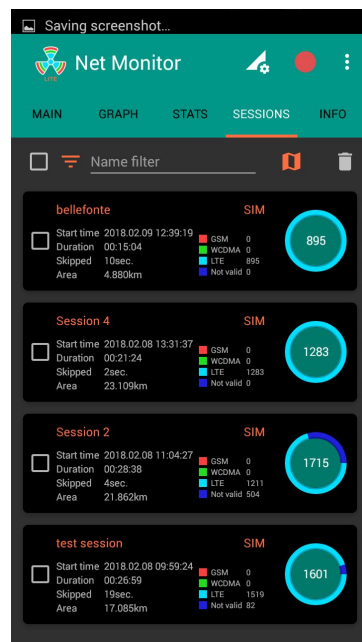
3. Hold your finger down on the session you just recorded until the "Choose action" pop up dialog appears:
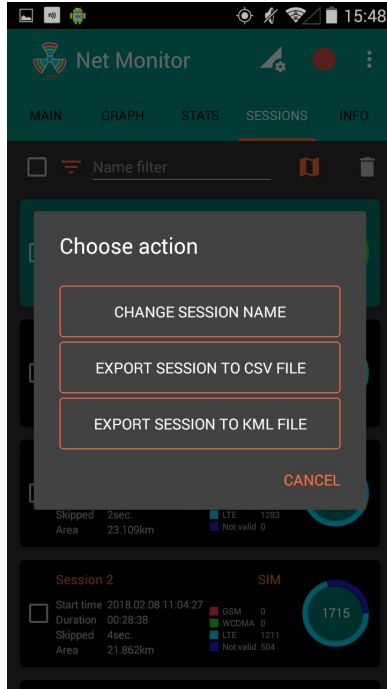
4. Select "Change Session Name" and create a session name that follows the prescribed format (see above for example):
cellular_<mmddyy>_<carrier>_<generation>_<location>

Data Export and Extraction

Once you are ready to extract your data from the phone for storage, transmission, and analysis, follow these steps:

1. Navigate to the "Sessions" screen.
2. Hold your finger down on the session you'd like to export until the "Choose action" pop up dialog appears.
3. Select "EXPORT SESSION TO CSV FILE".
4. Your phone will then export the data to its internal file system, and tell you where it is located in a follow-up pop-up dialog:
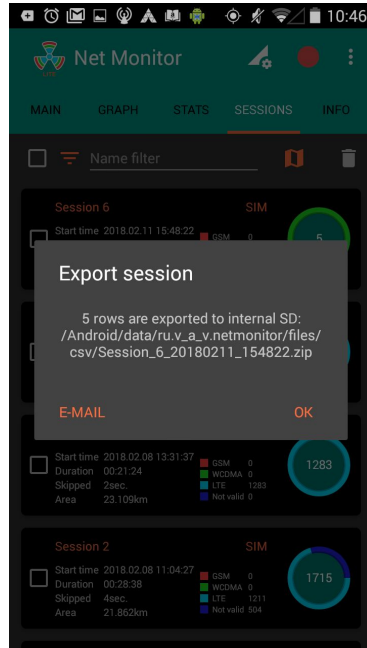
5. Select "Ok" to end the export process.

At this point, the data has been exported to a CSV file within your phone's internal file system. Now you can transmit the file from your phone to your computer by the multiple methods described above. Your file should be located at:

CSV Export: /Android/data/ru_v_a.netmonitor/files/csv/...
KML Export: /Android/data/ru_v_a.netmonitor/files/kml/...

Clearing App Data

To clear the data from the phone, you simply have to delete the session record:
1. Navigate to the "Sessions" tab within the app.
2. You will see a list of all the sessions you've recorded.
3. Click the check box on the left of each session you wish to delete from phone memory.
4. Once you have selected the sessions you wish to delete, tap the trash can icon in the upper right of the screen.
5. Tap "YES" to confirm your decision to delete the session(s).

Your sessions are now cleared.

Data Cleaning

Once you have your CSV file on your local computer, you can clean the data for analysis. NetMonitorLite csv data has a large number of column headings, but the ones that are of particular interest are:
1. "sim_state"

2. "lat" (latitude)
3. "long" (longitude)
4. "rssi" (received signal strength indication)

The data will need to be cleaned according to the data in #2, #3, and #4, and #1 should provide a clue as to whether the collected data point is viable. How to tell if a data point is viable:

1. If the geo-coordinates are set to "-1", then the data point could not get a GPS location, and is an unviable data point.
2. If the rssi value is an arbitrarily high number (2.15E+09) then NML failed to measure the signal strength at that data point, and is an unviable data point.
3. If the sim_state is "NOT_READY", then this is an indicator that either the geo-coordinates or the rssi value was not measured correctly, and this is likely a clue that this is not a viable data point.

Before this data can be analyzed, data points with bad geo-coordinates and rssi values will need to be culled from the data set. The easiest way to do this is in Excel, using the Filtering options to clean the data:

1. First, make a backup of the data before you edit it, in case you make a mistake.
2. Although NML exports to csv, the fields are actually ";"/semicolon delimited in its raw form. To prepare for opening this in Excel, open up the CSV file in your favorite lightweight text editor (Notepad should work just fine) and replace all ";" with ",", using the Ctrl+h keyboard shortcut.
3. Once you've saved the edited version, open the file up in Excel, and ensure that the data is sorted across its fields correctly.
4. Navigate to the "Data" toolbar in Excel, and Select "Filter":
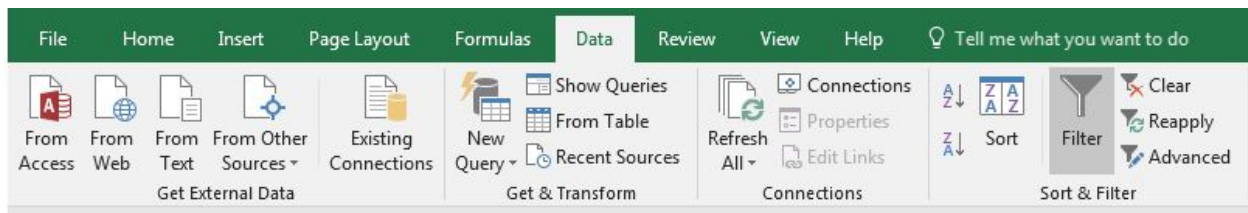
5. Your column headings will now have drop-down menu options, that will allow you to filter the data to show only rows that meet certain criteria:

sm_ne	umts_n	lte_nei	rssi_str	tech	mcc	mnc	lac_tac	node_i	cid	psc_pci	rssi	rs
0	0	2	-104	LTE	311	480	6170					
0	0	2	-104	LTE	311	480	6170					
0	0	2	-104	LTE	311	480	6170					
0	0	2	-102	LTE	311	480	6170					
0	0	2	-102	LTE	311	480	6170					
0	0	2	-103	LTE	311	480	6170					
0	0	2	-103	LTE	311	480	6170					
0	0	1	-103	LTE	311	480	6170					
0	0	1	-103	LTE	311	480	6170					
0	0	2	-100	LTE	311	480	6170					
0	0	2	-100	LTE	311	480	6170					
0	0	2	-95	LTE	311	480	6170					
0	0	2	-95	LTE	311	480	6170					
0	0	2	-93	LTE	311	480	6170					
0	0	2	-93	LTE	311	480	6170					
0	0	2	-93	LTE	311	480	6170					
0	0	2	-90	LTE	311	480	6170					
0	0	2	-90	LTE	311	480	6170					
0	0	2	-89	LTE	311	480	6170					
0	0	2	-89	LTE	311	480	6170					
0	0	2	-87	LTE	311	480	61707	241713	3	236	-86	

Filter dropdown menu (over columns U–X):

- Sort Smallest to Largest
- Sort Largest to Smallest
- Sort by Color ▸
- Clear Filter From "rssi"
- Filter by Color ▸
- ✓ Number Filters ▸
- Search 🔍
  - ☐ (Select All)
  - ☐ -117
  - ☐ -116
  - ☐ -115
  - ☐ -114
  - ☐ -113
  - ☐ -112
  - ☐ -111
  - ☐ -110
  - ☐ -109
- [OK] [Cancel]

6. Set the following Filters:
   a. rssi -> Number Filters -> Less than (transition to pop-up dialog box) -> is less than 300 -> OK
   b. lat -> Number Filters -> Does Not Equal (transition to pop-up dialog box) -> does not equal -1 -> OK
   c. long -> Number Filters -> Does Not Equal (transition to pop-up dialog box) -> does not equal -1 -> OK
7. Now, the only data that's appearing is the cleaned data. At this point, you can leave this excel sheet as is (ArcGIS can take excel data without conversion) or you can export the worksheet back into CSV. Personally, If you do edit in excel, I'd prefer you leave it in that format.

WIFI MONITORING AND MEASURING ("WARDRIVING") VIA WIGLE WIFI
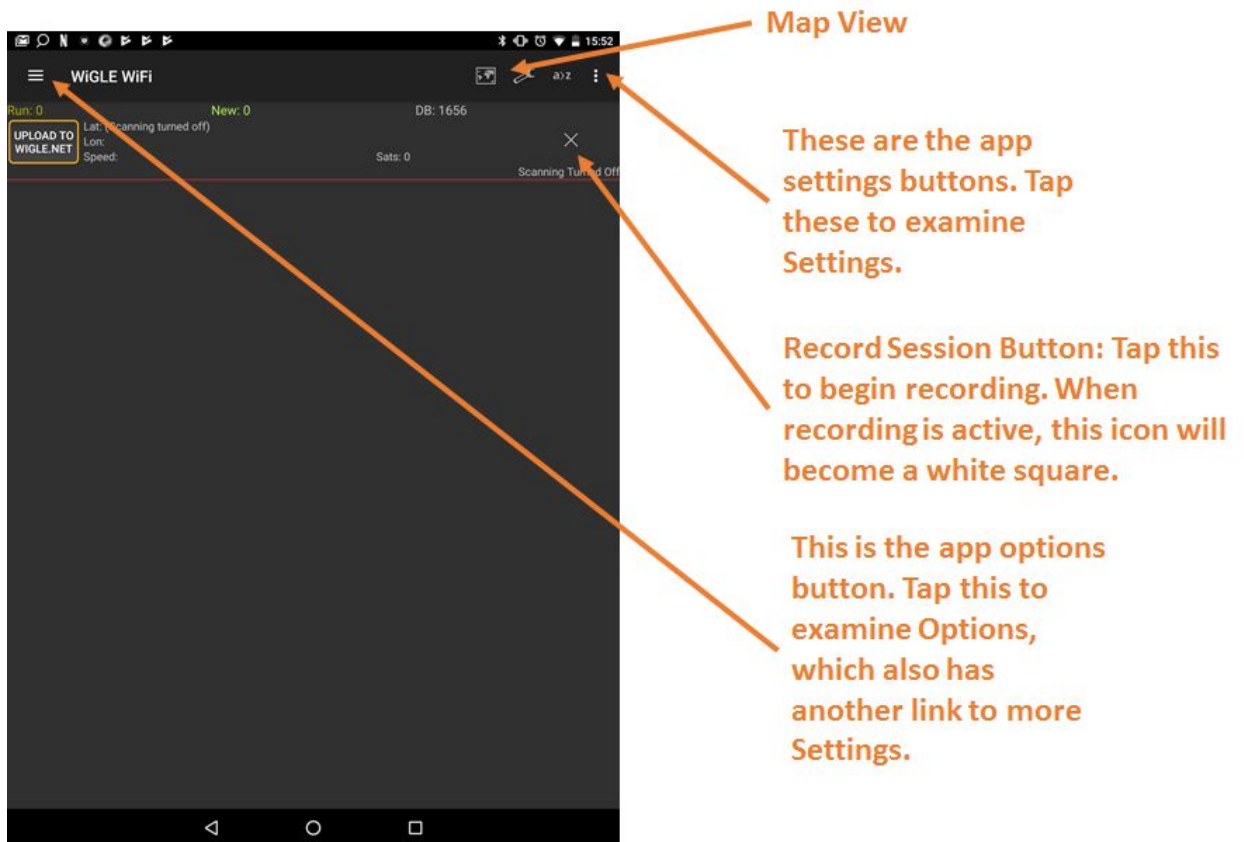
Purpose of this App
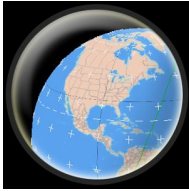
This app is used to detect the presence of WiFi hotspots at certain locations. **While this app can detect the presence of WiFi hotspots at your location it does not record the location of the actual modem that is being detected.** Thus, this app is useful for measuring WiFi availability at certain locations, but it does not get the geographic coordinates of the router it is detecting.

Installing and Configuring The App

Navigate to the WiGLE WiFi Wardriving app in the Google PlayStore, and install it on your Android Device:
https://play.google.com/store/apps/details?id=net.wigle.wigleandroid

Once installed, the home screen of the app should look like this (i did my tests on an android tablet with this app, so your screen may look a little more cramped but should still have the same content):

Map View

These are the app settings buttons. Tap these to examine Settings.

Record Session Button: Tap this to begin recording. When recording is active, this icon will become a white square.

This is the app options button. Tap this to examine Options, which also has another link to more Settings.

There are several options for settings, but you should be able to leave it most in their default configuration for detecting WiFi hotspots.
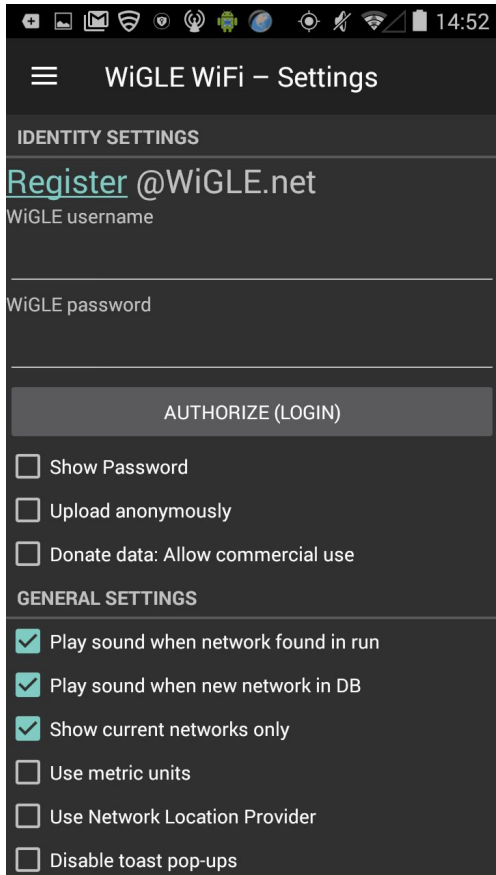
However, what you should adjust is the scan settings for sampling intervals, which in WiGLE is speed dependent. To view these settings:

1. Tap the three-bar Options button in the upper left of the home screen for the app. A drop down menu will appear:
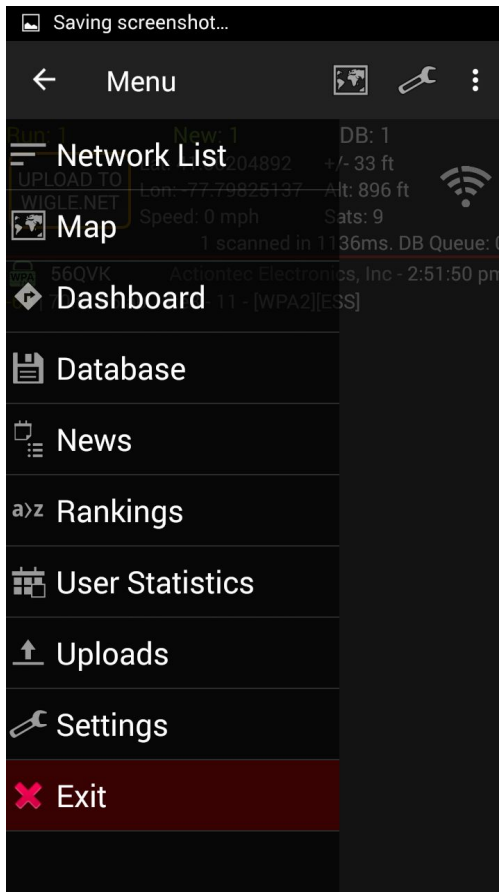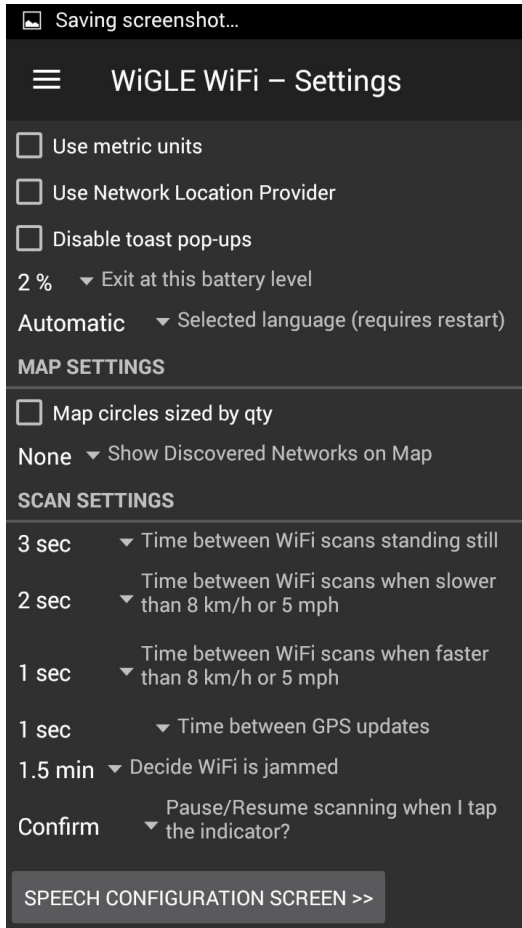

2. From this drop down menu, select "Settings". You will transition to the settings screen:

3. Scroll down to "SCAN SETTINGS" and set your configuration for sampling intervals and decision timing:

☰   WiGLE WiFi – Settings

☐ Use metric units

☐ Use Network Location Provider

☐ Disable toast pop-ups

2 %   ▼ Exit at this battery level

Automatic   ▼ Selected language (requires restart)

MAP SETTINGS

☐ Map circles sized by qty

None   ▼ Show Discovered Networks on Map

SCAN SETTINGS

3 sec   ▼ Time between WiFi scans standing still

2 sec   ▼ Time between WiFi scans when slower than 8 km/h or 5 mph

1 sec   ▼ Time between WiFi scans when faster than 8 km/h or 5 mph

1 sec   ▼ Time between GPS updates

1.5 min   ▼ Decide WiFi is jammed

Confirm   ▼ Pause/Resume scanning when I tap the indicator?

SPEECH CONFIGURATION SCREEN >>

Data Collection

Once you are ready to begin your data collection, follow these steps:

1. Open up the WiGLE WiFi App
2. Tap the "X" in the upper right corner of the Home screen to begin recording your session (it will turn into a WiFi symbol with a measurement arm oscillating back and forth when the recording session is active).
3. Turn off the screen display to preserve battery.
4. Stow phone away in safe place, and minimize jostling to avoid accidental termination of session

Once you have completed your recording session, tap the oscillating WiFi symbol in the upper right corner of the home screen to end the session, which will cause it to turn back into the grey "X".

At this point your data has been saved into an internal .sqlite database. You will want to backup this database. To do this, follow these steps:

1. Navigate to the "Database" via the three-bar options button in the upper left of the home screen.

2. Scroll down to the "BACKUP DATABASE" button and tap that button. This will backup your database.

Data Export and Extraction

Once you are ready to extract your data from the phone for storage, transmission, and analysis, follow these steps:

1. Navigate to the "Database" via the three-bar options button in the upper left of the home screen.
2. Scroll down to the Export options, of which there will be 4:
    a. CSV EXPORT RUN
    b. KML EXPORT RUN
    c. CSV EXPORT DATABASE
    d. KML EXPORT DATABASE
3. EXPORT RUN: will only export the data from the last session to file
4. EXPORT DATABASE: will export ALL of the data you've collected. Thus, if you've only run one session on your app, then these two export options are equivalent. If you are clearing your database at the end of every day after you've extracted your data to your computer, you can just export to database to make sure that you don't lose any measurements.
5. Select whichever *.CSV option you wish to export to, and make note of the exported file name and path:
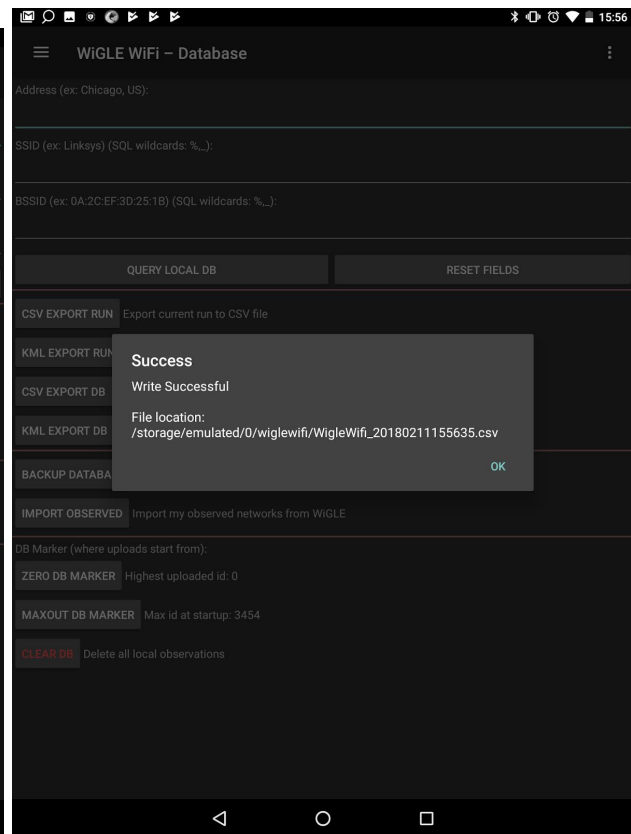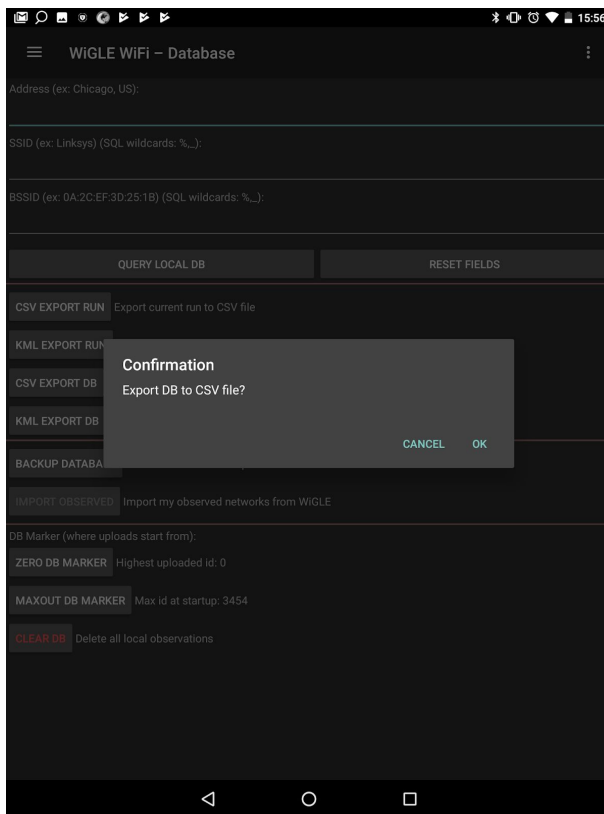
At this point, your data has been exported to a *.csv file on your phone's local file system, and can be transmitted to your computer by the multiple methods described above. Your file should be located at:

/wiglewifi/...

Once you have finished extracting your data and moved it to your computer, and are certain that it is safe, you will want to clear the database for the next run.

Clearing App Data

To clear the app data, follow these steps:
1. First, ensure that the data you collected through the app is now exported, extracted, and verified as safe away from the phone.
2. Tap the three bar "Options" menu in the upper left of the screen.
3. Scroll down to "Database" and tap it to enter the database options.
4. Scroll down to "BACKUP DATABASE" and tap it (ALWAYS backup the database before clearing the lcal observations).
   a. Click "OK" to confirm the "Backup DB to a different file". If I need it, i can find it in the phone now.
5. Back within the "Database" screen, scroll down to the "CLEAR DB" button (the text is red) and tap it.
   a. Click OK to confirm the clearance.

Your app is now clear of data.

Data Cleaning

Once you have your CSV file on your local computer, you can clean the data for analysis. First of all, the default top row of the CSV file is information about the app and device. Remove this before analysis, as it will confuse the GIS system.

The WiGLE WiFi data has several column headings in this file, but the ones of particular interest are:
1. "MAC" (the identifier of a particular network control device, e.g. a router)
2. "SSID" (the name of the detected WiFi network)
3. "RSSI" (received signal strength indicator)
4. CurrentLatitude
5. CurrentLongitude

WiGLE WiFI does a good job of not polluting the RSSI, latitude and longitude measures, but it does measure the same access point multiple times, as well as the same WiFi network having multiple access points. This respectively means two kinds of redundancy:

1. The same SSID will show up multiple times. Filter duplicates of the SSID field will result in data the covers just networks, but ignores the existence of multiple access points.
2. The same MAC ID will show up multiple times. Filter duplicates of the MAC field will result in data that covers the same network multiple times, but captures the existence of multiple access points, and their respective measures.

Before this data can be analyzed, one of these two types of de-redundatizing the data must occur. The easiest way to do this is in Excel, using the "Remove Duplicates" option to clean the data:
1. First, make a backup of the data before you edit it, in case you make a mistake.
2. Once you have the data backed up and opened up in Excel, delete the first row that contains "about" information.
3. Navigate to teh "Data" toolbar in Excel, and select "Remove Duplicates":
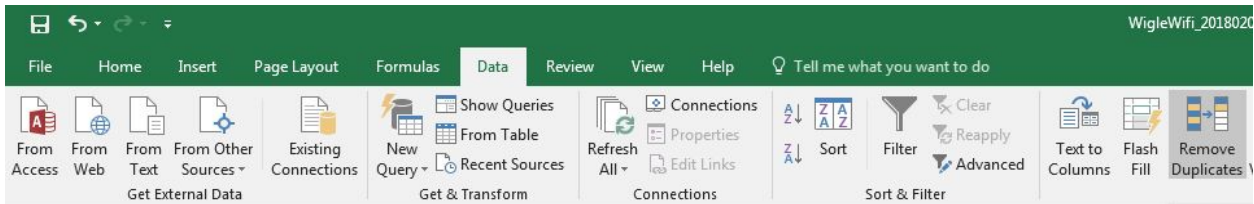
4. A Pop-up Dialog box will appear:
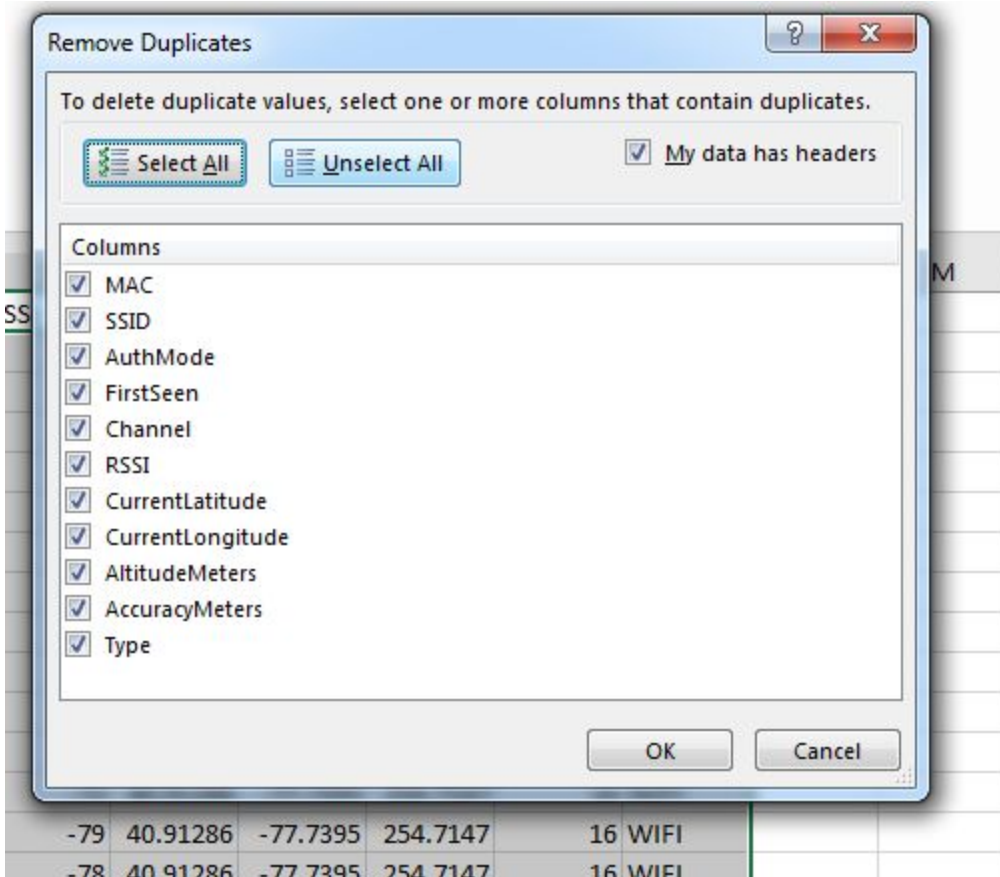
5. From here, select "Unselect All", and then select either MAC or SSID, whichever type of analysis you'd prefer. Make sure to leave the "My data has headers" box is checked.
6. Click OK. This will close the window, and new pop-up window will tell you what it removed:
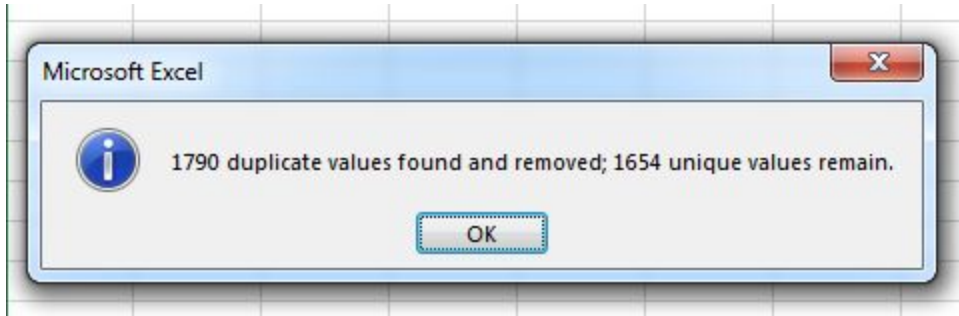

7. Now, the only data that's appearing is the cleaned data. At this point, you can leave this excel sheet as is (ArcGIS can take excel data without conversion) or you can export the worksheet back into CSV. Personally, If you do edit in excel, I'd prefer you leave it in that format.

NOTE: This method of de-redundatizing the data only takes the first measure that is seen by Excel. Unfortunately, this results in the loss of data, so is only a quick measure. A better way to preserve the data is to take the average of the measurements across all unique MAC IDs or unique SSIDs, but this would take more time to do, especially since WiGLE captures a lot of data points. We should do this for the "official" data, but this quick and dirty method de-redundatizing is acceptable for rapid turnaround in my opinion.

CELLULAR TOWER MAPPING VIA CELL MAP

Purpose of this App
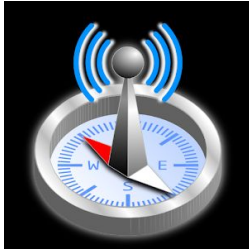
This app is used to try to identify the location of cellular signal sources (towers typically, but could be much smaller signal propagation devices typically referred to as "cells"). **In order to identify the latitude/longitude coordinates of the cells, it requires a WiFi/Internet connection during measurement**. Otherwise, you will not get a cells location, just information that shows its existence.

Installing and Configuring The App

Navigate to the Cell Map app in the Google PlayStore, and install it on your Android Device: https://play.google.com/store/apps/details?id=com.eartoearoak.cellmap

Once installed, the home screen of the app should look like this:
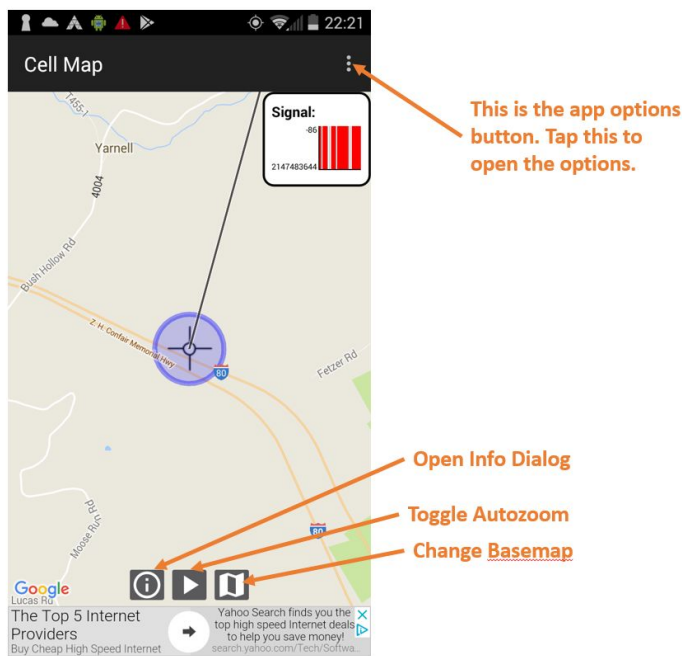
If you are driving around, you can use this map view to see the location of cells relative to your location, and go and find them for yourself if you're willing and capable of getting to its location. If you tap the options button, a drop down dialog box will open up:
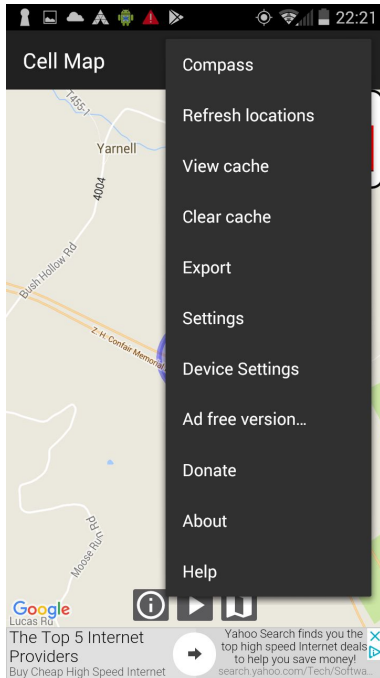
Data Collection

Once you open this app, it is automatically collecting data, so you don't need to activate it. However, you should monitor it, which involves navigating to the "Info" window to see what cells you are currently detecting and recording:

1. On the home screen, tap on the info icon in the lower section on the screen, which is a little "i" with a circle around it.
2. When you tap on it, a pop up window will appear with the currently detected cells:
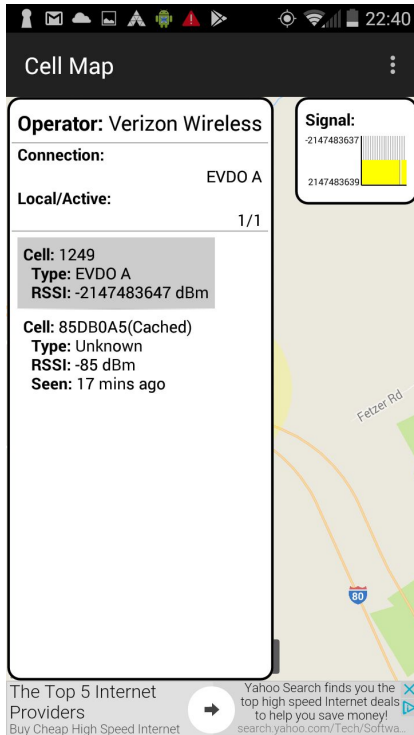
3. To exit this view, press the Android "Back" button, which may cause you to leave the app and return to the home screen. Don't worry, just reopen the app and it will return you to the default map view.

You can also view what data you have collected so far, by opening "View Cache" window:

1. Open the "Option" view by tapping on the three-dot options button in the upper right corner of the screen.
2. Scroll down to "View Cache" and tap to open up a list of currently recorded cells:

| Cell	Type	RSSI (dBm)	Seen
0268	LTE	-2147483647	2 days ago
027C	LTE	-2147483647	2 days ago
1131	LTE	-2147483647	2 days ago
1231	LTE	-2147483647	2 days ago
1249	EVDO A	-2147483647	34 secs ag
1331	LTE	-2147483647	2 days ago
1339	LTE	-2147483647	2 days ago
3ADD016	LTE	-100	2 days ago
3AE5316	LTE	-110	2 days ago
3AE8D16	LTE	-104	2 days ago
3AE990C	LTE	-83	2 days ago
3AE9916	LTE	-88	2 days ago
3AEA10C	LTE	-82	2 days ago

OK

Data Export and Extraction

Once you are ready to extract your data from the phone for storage, transmission, and analysis, follow these steps:

1. Open the Options view by tapping the three-dot options button in the upper right corner of the screen.
2. Scroll down to "Export" and tap it to enter the Export dialog box:
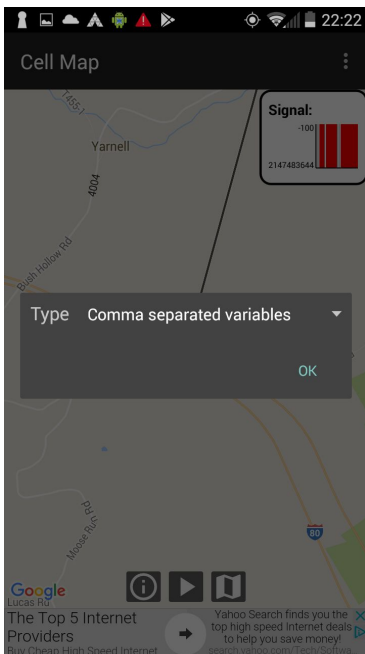
3. Here you can select what output format: Comma separated values (CSV) or Google Earth (kml). I recommend staying with (CSV).
4. Once you have selected your output format, tap "Ok". This will open a dialog window allowing you to select your output file location:
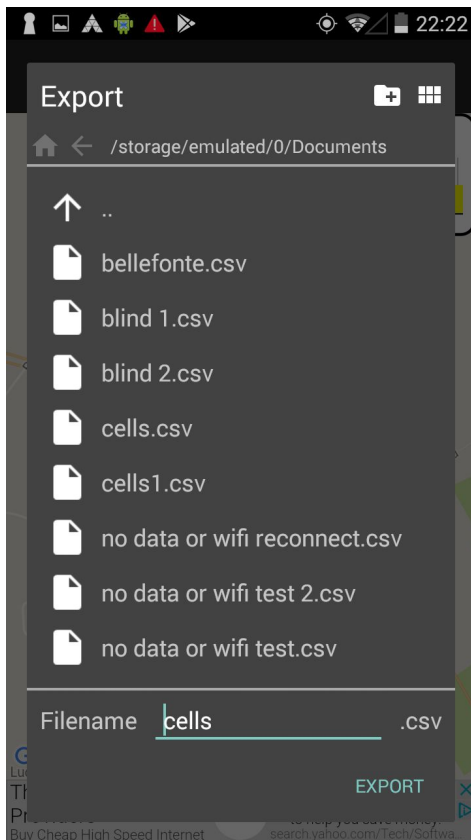
5. You can select your output location within this dialog box. You can navigate by using the up arrow in the Export dialog to move up one level in the directory, or select a sub-folder to enter it. You can also create a folder by tapping on the folder with the plus sign icon in the upper left of the screen. This way, you can ensure that the file is placed into a location you can clearly identify later.
6. Once you have selected a location and given a descriptive name to your file, select "EXPORT" in the lower right corner of the dialog window.

At this point, your data has been exported to a *.csv file on your phone's local file system, and can be transmitted to your computer by the multiple methods described above. Your file should be located at wherever you directed it to. By default, it is located at:

/Documents/...

Clearing App Data

Once you have finished extracting your data and moved it to your computer, and are certain that it is safe, you maywant to clear your cache for another data collection run: To clear the app data, follow these steps:

1. First, ensure that the data you collected through the app is now exported, extracted, and verified as safe away from the phone.
2. Tap the three dot "Options" menu in the upper
3. Scroll down to "Clear Cache" tap it.
   a. Tap "OK" to confirm clearing the cache.

Data Cleaning

Once you have your CSV file on your local computer, you can clean the data for analysis. The Cell Map data has a few column headings in this file:

1. "Id" (Id for the cell)
2. "Type" (Type of cell, e.g. LTE)
3. "Strength" (Received Signal Strength Indicator, RSSI)
4. "Lat" (Latitude of the cell)
5. "Lon" (Longitude of the cell)
6. "Seen" (Timestamp of observation)

The data will need to be cleaned according to the data in #3, #4, and #5, as some measurements can be failures. How to tell if a data point is viable:

1. If the Strength value is an arbitrarily low number (-2.1E+09) then Cell Map failed to measure the signal strength at that data point, and is an unviable data point.
2. If the Lat or Lon is "null", then Cell Map was unable to verify the location of the Cell.

Before this data can be analyzed, data points with null geo-coordinates will need to be culled from the data set. It may not be necessary to filter based on the missed Strength values, especially if you're interested in the location and not necessarily the signal strength of the cell. The easiest way to do this is in Excel, using the Filtering options to clean the data.

1. First, make a backup of the data before you edit it, in case you make a mistake.
2. Once you've saved the edited version, open the file up in Excel, and ensure that the data is sorted across its fields correctly.
3. Navigate to the "Data" toolbar in Excel, and Select "Filter":
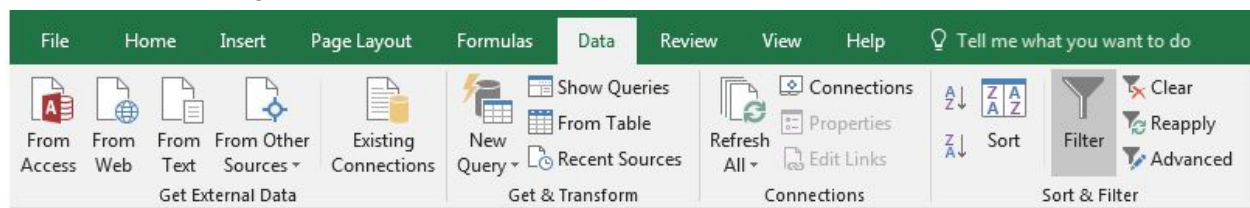
4. Your column headings will now have drop-down menu options, that will allow you to filter the data to show only rows that meet certain criteria:

	A	B	C	D	E	F	G	H
1	Id	Type	Streng	Lat	Lon	Seen		
2	268	LTE	-2.1E+09	39.68045	-90.3672	2018-02-14T20:37:25.000-0500		
3	27C	LTE	-2.1E+09	null	null	2018-02-14T22:57:19.000-0500		
4	549	LTE	-2.1F+09	34.09235	-94.9598	2018-02-14T20:11:50.000-0500		

5. Set the following filters:
   a. Lat -> uncheck "null" in the drop down box dialog:
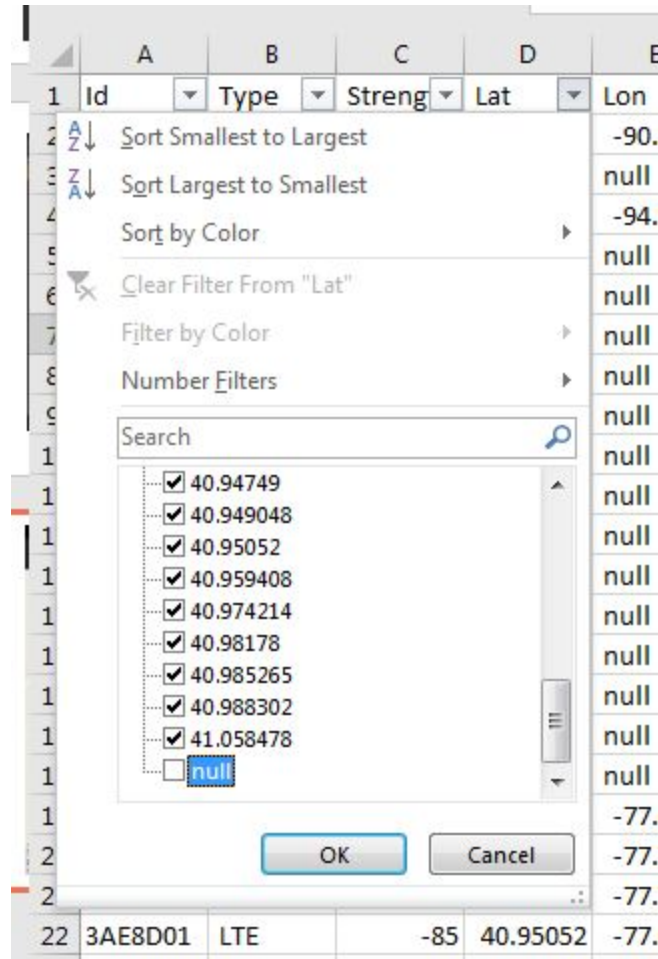
   b. Lon -> uncheck "null" in the drop down box dialog.
   c. (OPTIONAL) Strength -> Number Filters -> Greater than (transition to pop-up dialog box) -> is greater than -300 -> OK
6. Now, the only data that's appearing is the cleaned data. At this point, you can leave this excel sheet as is (ArcGIS can take excel data without conversion) or you can export the worksheet back into CSV. Personally, If you do edit in excel, I'd prefer you leave it in that format.

ANDROID PHONE MEASURING RIG: SOME RECOMMENDATIONS

Maximize Data Safety and Integrity

As you would expect, many of these apps can get a lot of measurements, as well as moving files around manually can be risky if you're not careful. To minimize chaos:
- Before you edit files (if you must) back up the original file. It could be as simple as a copy-paste, but goes a long way to securing your data.
- Use clear naming conventions on your files, so you can know at a glance where, what, and how the data was collected.
- Before you clear logs, caches, or data on your apps, make sure that you have the exported data and can view it independently on your computer.

Maximize Power Efficiency

Many of these apps take a lot of juice to keep running. To minimize the chance that your phones die during measuring:
- Charge each phone at night to full charge
- Charge each auxiliary batter at night to full charge
- Monitor your phones regularly throughout the day, to check that battery levels are acceptable. Plug in the auxiliary batteries when necessary.
- Set the sampling interval on your apps to a reasonable interval (e.g. an extreme example would be .25 second intervals over 9 hours of measurements. Too much energy, too much data usage).
- Ensure that the apps are running without the screen on. Some apps allow you to enforce that the screen stays lit when the app is running. This will destroy your battery power over the measurement time.