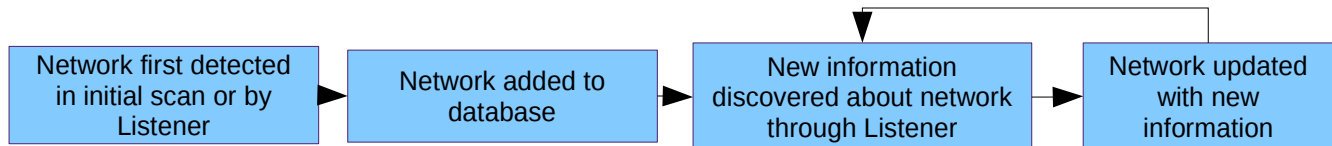


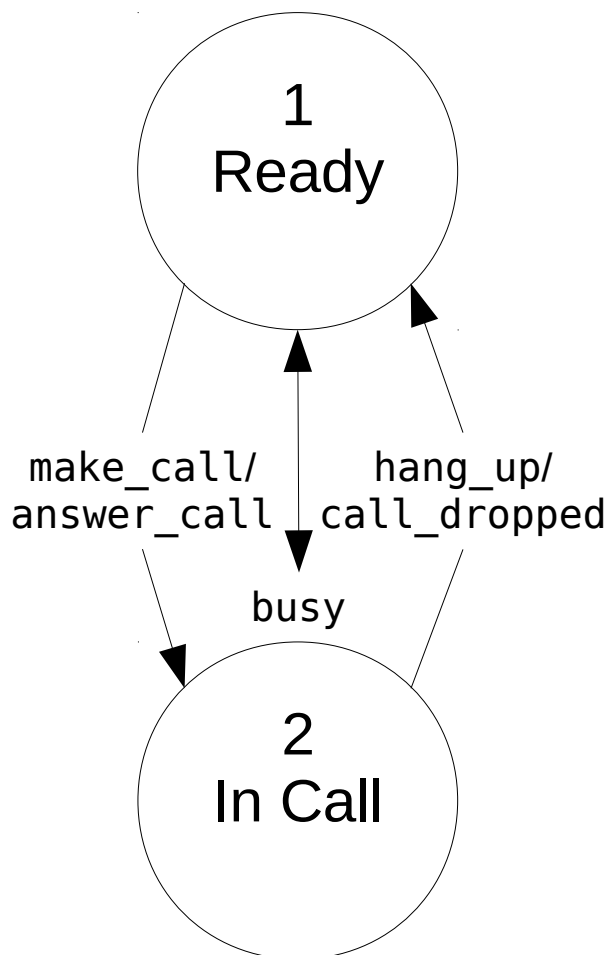
## Project 3

### Event Chart

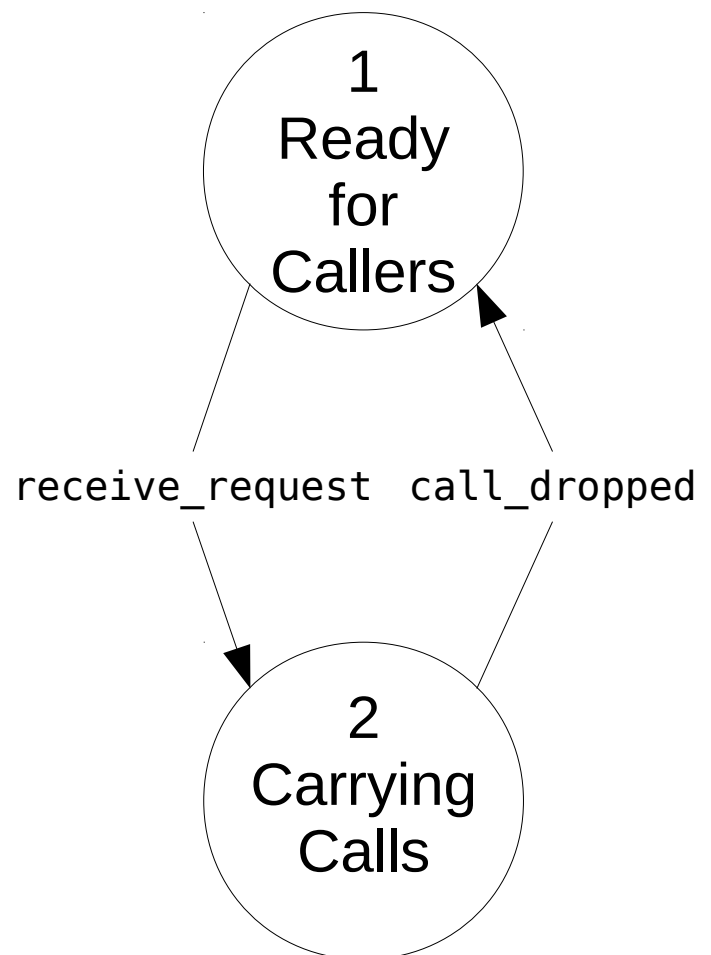


### State Diagrams

#### Phone (MS1/MS2)

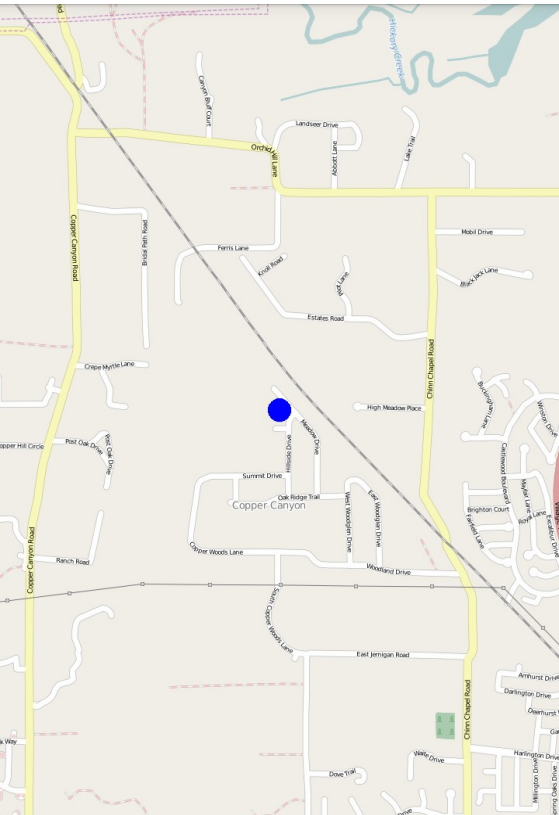


#### Tower (BS1/BS2)



**Demo (Maps are from OpenStreetMaps, not Google Maps)**

**Home**



**Cell Networks**

ID	Network Type	Location Area Code	Mobile Network Code	Mobile Country Code	Latitude	Longitude	Range
134682641	LTE	27195	410	310	33.1	-97.1	

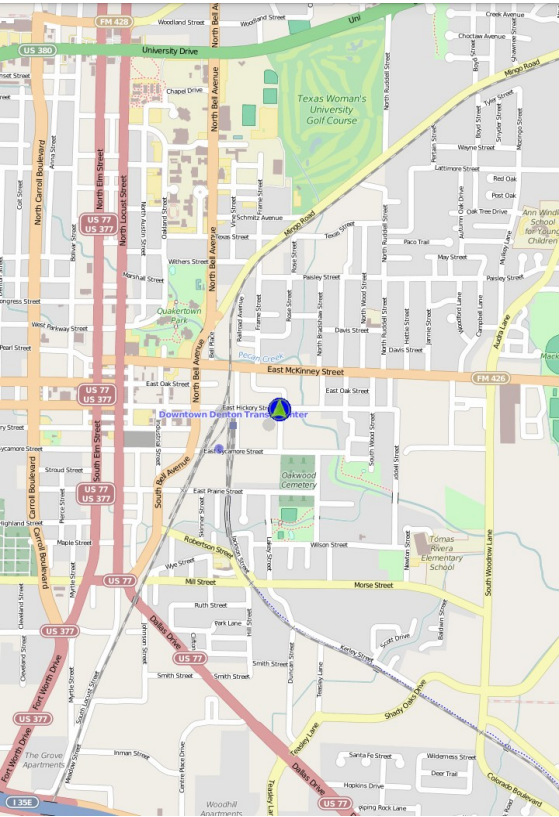
**Wi-Fi Networks**

BSSID	SSID	Channel	Encryption Type	Uses WPS	Uses ESS	Latitude	Longitude	Range
00:1f:90:e5:59:4d	JWQVK	8	WPA2	false	true	33.1	-97.1	55
b0:a7:37:1e:6f:39	DIRECT-roku-949	8	WPA2	true	true			
00:18:01:f1:17RV23		11	WEP	false	true			

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8:aa				
00:1f:90:e8:1	JWQVK	4 WPA2	false	true
0:5e				
00:1d:19:e1:	EGETK	11 WEP	false	true
82:cf				

On the A-Train



Cell Networks

ID	Network Type	Location Area Code	Mobile Network Code	Mobile Country Code	Latitude	Longitude	Range
134682641	LTE				33.09	-97.03	
134694664	Unknown	27195	410	310			
134694671	Unknown	27195	410	310			
133122576	Unknown	27195	410	310			
134682640	Unknown	27195	410	310			
134682633	Unknown	27195	410	310			

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134682632 Unknown	27195	410	310		
134682639 Unknown	27195	410	310		
133270800 Unknown	27195	410	310		
133270799 Unknown	27195	410	310		
133270792 Unknown	27195	410	310		
133465602 Unknown	27195	410	310		
133184015 Unknown	27195	410	310		
133619473 Unknown	27195	410	310		
133501186 Unknown	27210	410	310		
133151760 Unknown	27210	410	310		
2147483647 Unknown	27210	410	310		
134668545 Unknown	27210	410	310		
134668552 Unknown	27210	410	310		
134668559 Unknown	27210	410	310		
133520386 Unknown	27210	410	310		
134706689 Unknown	27210	410	310		
134684176 Unknown	27210	410	310	33.22	-97.13
133204240 Unknown	27210	410	310		
134684169 Unknown	27210	410	310		
134684170 LTE	27210	410	310	33.22	-97.13

## Wi-Fi Networks

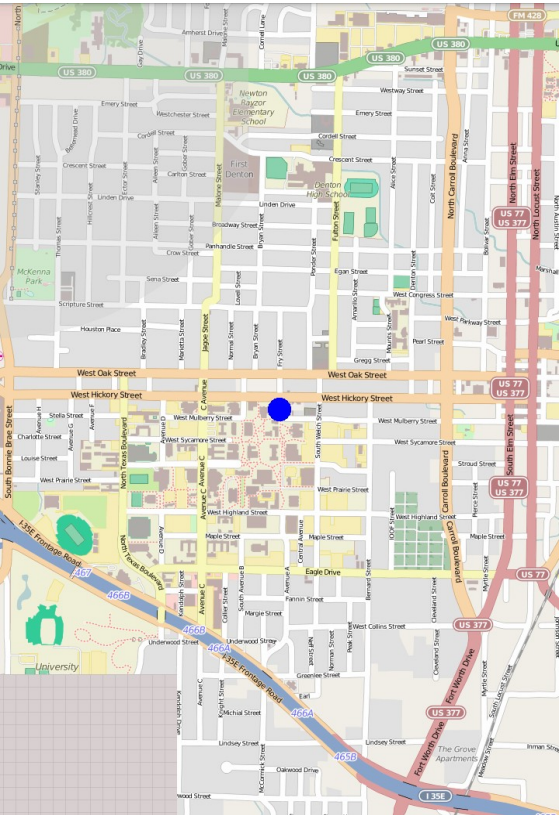
BSSID	SSID	Channel	Encryption Type	Uses WPS	Uses ESS	Latitude	Longitude	Range
f8:0c:f3:d6:87:33	clifton	6	WPA2	false	true			
00:7f:28:48:74:fa	MBQQ8	6	WPA2	false	true			
4c:ed:de:50:16:e0	3HXGQ	1	WEP	false	true			
ac:5d:10:b9:25:1a	ATT158	6	WPA2	false	true			
c8:d7:19:92:92:5b	SinghIsKing2	2	WPA2	true	true			
00:18:01:f4:c2:e2	2HUT3	11	WEP	false	true			
02:2e:ee:ab:86:a7	Trimble Service (5343526512)	7	WEP	false	false			
78:61:7c:82:5b:96	WiFi Hotspot 6610	11	WPA2	false	true			
00:24:d2:90:96:1e	JTRXK	1	WPA2	false	true			
00:23:08:10:86:07	FSTSG	11	WEP	false	true			
f8:0c:f3:d6:87:33	clifton	6	WPA2	false	true			

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78:61:7c:66:92:30	WiFi Hotspot 5018	11 WPA2	false	true
c4:3d:c7:a1:c3:c4	ALBERT- PC_Network	9 WPA2	true	true
bc:16:f5:1a:0b:40	City of Denton Outdoor WiFi	1 Open	false	true
00:02:6f:a1:aa:d4	DDTC-Wifi	11 Open	false	true
d8:fe:e3:c4:7f:8a	RGRS-GUEST wifi	1 Open	false	true
00:02:6f:a1:aa:c8	DDTC-Wifi2	7 Open	false	true
f8:e4:fb:fa:17:2b	2N27T	11 WPA2	false	true
c0:3f:0e:2c:0f:0c	VELTECH-01- PC_Network	1 WPA2	true	true
bc:16:f5:1a:06:80	City of Denton Outdoor WiFi	11 Open	false	true
00:02:6f:a1:aa:c0	DDTC-Admin	11 WPA	false	true
00:18:f8:ce:e7:47	AB-Warehouse	11 WPA2	false	true
02:23:63:87:b2:82	HP8D5A2F	10 Open	false	false

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To UNT Main Campus



Cell Networks

ID	Network Type	Location Area Code	Mobile Network Code	Mobile Country Code	Latitude	Longitude	Range
134684170	LTE	27210	410	310	33.22	-97.13	
134684169	Unknown	27210	410	310			
133618697	Unknown	27210	410	310			
133618696	Unknown	27210	410	310			
133618698	Unknown	27210	410	310			
134670601	Unknown	27210	410	310			

Wi-Fi Networks

BSSID	SSID	Channel	Encryption Type	Uses WPS	Uses ESS	Latitude	Longitude	Range
00:02:6f:a1:aa:d4	DDTC-Wifi	11	Open	false	true			

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d8:fe:e3:c4:7f:8a	RGRS-GUEST wifi	1 Open	false	true			
00:02:6f:a1:aa:c8	DDTC-Wifi2	7 Open	false	true			
f8:e4:fb:fa:17:2b	2N27T	11 WPA2	false	true			
c0:3f:0e:2c:0f:0c	VELTECH-01-PC_Network	1 WPA2	true	true			
bc:16:f5:1a:06:80	City of Denton Outdoor WiFi	11 Open	false	true			
00:02:6f:a1:aa:c0	DDTC-Admin	11 WPA	false	true			
00:18:f8:ce:e7:47	AB-Warehouse	11 WPA2	false	true			
02:23:63:87:b2:82	HP8D5A2F	10 Open	false	false			
00:02:6f:a1:aa:c4	DDTC-Admin	11 WPA	false	true			
bc:16:f5:1a:0b:40	City of Denton Outdoor WiFi	1 Open	false	true	33.21	-97.13	42
00:19:56:e9:33:f0		9 WEP	false	true			
00:07:7d:14:c2:33	AustinBaker	2 WPA2	true	true			
0c:27:24:87:7c:91		11 WPA2	false	true			
0c:27:24:87:7c:90	COD Public Internet - 24hr	11 Open	false	true			
18:9c:5d:40:9b:b0	COD Public Internet - 24hr	1 Open	false	true			
bc:16:f5:1a:06:80	City of Denton	11 Open	false	true	33.21	-97.12	60

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	Outdoor WiFi							
e8:ed:f3:cc:85:51	City of Denton Public Internet	1 Open	false	true				
bc:16:f5:1a:06:80	City of Denton Outdoor WiFi	11 Open	false	true	33.21	-97.13	36	
bc:16:f5:1a:06:80	City of Denton Outdoor WiFi	11 Open	false	true	33.21	-97.13	61	
68:94:23:c0:1a:30	HP-Print- 30-LaserJet 200 color	6 WPA2	false	true				
24:a4:3c:fc:25:c4	Alti_Test	11 WPA2	false	true				
bc:16:f5:1a:1c:a0	City of Denton Outdoor WiFi	6 Open	false	true	33.21	-97.13	43	
0a:90:7f:25:33:57	TBBI	1 WPA2	false	true				
70:56:81:cc:de:c5	Marchman's Wi-Fi Network	11 WPA2	false	true				
70:56:81:cc:de:c6	Marchman's Wi-Fi Network	149 WPA2	false	true				
74:d0:2b:db:80:40	GDAC_Pri vate_RPT	6 WPA2	false	true				
e0:3f:49:92:c5:41	GDAC_Gu est1	6 WPA2	false	true				
1c:3e:84:6f:b7:9c	HP-Print- 9c-EOC 2 HP LJ 400	11 Open	false	true				
00:7f:28:85:62:51	K5GDG	6 WPA2	false	true				
58:93:96:2c:bc:88	Cultivar	6 WPA2	false	true				



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f8:e4:fb:1a:58:2f	SXSG4	6 WPA2	false	true
18:1b:eb:ca:49:23	RDLRN	11 WPA2	false	true
f0:92:1c:97:9b:ea	HP-Print- EA- Officejet 6700	6 WPA2	false	true
00:02:6f:e6:e6:1a		36 Open	false	true
dc:a5:f4:64:2f:e2		11 WPA2	false	true
7c:d1:c3:cf:a8:cc	Cultivar Guest	11 WPA2	false	true
dc:a5:f4:64:36:11	COD Public Internet - 24hr	1 Open	false	true
dc:a5:f4:64:2f:e1	COD Public Internet - 24hr	11 Open	false	true
02:2a:6a:08:1e:07	HPE710n.6 012B9	6 Open	false	false
e0:3f:49:92:c5:40	GDAC_Pri vate	6 WPA2	true	true
18:1b:eb:26:24:5b	M9JK5	11 WPA2	false	true
d4:c9:ef:ec:2f:ab	HP-Print- AB- Officejet 6700	1 Open	false	true
00:1a:8c:29:b1:a0	Frontier	1 WPA2	false	true
c0:c1:c0:13:bf:b7	cactusville	1 WPA2	false	true
cc:b2:55:38:e6:de	dbbi	1 WPA2	true	true
74:44:01:71:48:fe	SheaRefl	2 WPA2	true	true
f8:c0:01:02:ba:02	SMC-Guest	11 WPA2	false	true
f8:c0:01:02:ba:00	SMC	11 WPA2	false	true
fc:15:b4:ab:c4:ce	HP-Print- CE- Officejet Pro 8610	11 WPA2	false	true

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e4:f4:c6:0d:c3:c5	apt2.4	3 WPA2	false	true
00:23:97:83:c8:d	09FX08066	6 WEP	false	true
f	742			
00:1d:19:da:fd:c3	XFYXS	6 WEP	false	true
00:24:d2:f6:1e:9	GEVWA	11 WEP	false	true
3				
00:24:d2:81:54:f	YHNPK	6 WEP	false	true
1				
00:26:b8:b6:80:a	GRFXL	6 WPA2	false	true
7				
18:1b:eb:02:4a:3	brucewillis	6 WPA2	false	true
5				
78:cd:8e:52:83:7	EASTSIDE	11 WPA2	false	true
8				
88:dc:96:07:7c:0	Queenies Steakhouse Staff	1 WPA2	false	true
0				
20:4e:7f:2c:68:d8	bobo225	11 WPA2	true	true
00:26:62:df:67:7	H3CQQ	1 WEP	false	true
8				
00:26:b6:42:bb:c	WCYJM	1 WEP	false	true
c				
00:15:05:d3:03:6	Actiontec	9 WPA	false	true
2				
dc:3a:5e:da:d3:0	DIRECT- roku-794- D5DC24	1 WPA2	true	true
7				
9c:d6:43:2a:75:5	GSATi- Guest	1 WPA2	false	true
1				
9c:d6:43:2a:75:5	GSATi	1 WPA2	false	true
0				
98:2c:be:18:f2:5a	2WIRE465	1 WPA2	false	true
04:a1:51:4c:ac:c0	Magnus	11 WPA	false	true
e4:f4:c6:0c:62:95	JARVIS	9 WPA2	true	true
96:10:3e:0e:c7:7	Denton- guest	3 Open	false	true
3				
20:0c:c8:3c:98:5	NETGEAR	6 WPA2	true	true
1	66			
08:86:3b:ff:07:5a	notfreeinter	1 WPA2	true	true

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	net			
94:10:3e:0e:c7:73	Denton	3 WPA2	true	true
00:1f:90:f2:b9:1f	ccc	6 WPA2	false	true
b0:05:94:2b:95:b5	PS4-6F36BAABD77B	6 WPA2	false	true
80:ea:96:ec:a8:1a	Drew's Wi-Fi Network	1 WPA2	false	true
20:0c:c8:0f:8b:ba01	NETGEAR	8 WPA2	true	true
3c:15:c2:f3:0d:6e		6 WPA2	false	true
00:1b:2f:0e:69:e8	GAILGEAR	6 WPA	false	true
90:f6:52:71:63:b		6 WPA2	false	true
ea:e0:eb:d2:8d:a3	Holmes's iPhone	1 WPA2	false	true
ec:1a:59:ac:2f:43	belkin.f43	11 WPA2	true	true
b4:75:0e:2a:4a:b2	belkin.ab0.media	44 WPA2	true	true
00:8e:f2:fa:b0:38	NETGEAR24	4 WPA2	false	true

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## ***Report***

### **Structure of the App**

My Project 3 app relies on three custom Services to store and retrieve the information it uses: `GPSretrieve`, for getting a user's location from either GPS, Wi-Fi, or cell towers (in that order of preference), `TowerInfoCommunicator`, for retrieving and storing information on cell towers, and `WiFiInfoCommunicator`, for retrieving and storing information on Wi-Fi networks. It takes this information and displays them in two places: An `OpenStreetMaps` (Google Maps requires an API key, something I didn't want to bother with for a school project) `MapView` that displays the user's location alongside overlays of the cellular and Wi-Fi signals they have encountered, and a data pane that displays information on the cellular and Wi-Fi signals the user is currently connected to. Additionally, the user can export this information to a CSV file either on the device or on the user's Google Drive account.

The Service structure I chose presents two advantages to this app – it allows Activities to save and access information without having to worry about which Activity collected it, and it allows the app to collect data even when none of its Activities are active. This also means I did not need to implement a database to access data across Activities, which presents a drawback: Once the app is dismissed by the system, all the data it has collected is gone. Unfortunately, this flaw persists since I determined that it would be too time-intensive for me to fix it.

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## The APIs I Used

To accomplish this, I used a series of APIs, both for the data collection, the exporting of data, and for the interface itself. All three of the services make heavy use of the `LocationManager` and `LocationListener` classes, as they provides not only GPS locations, but also cellular and Wi-Fi locations, which are used not only for mapping the user but for mapping and even determining the range of the networks they are connected to. In short, `LocationManager` and `LocationListener` are indispensable to this app. It also appears to be the only way to get GSM cell locations on Android without registering for an API key, as all the web APIs I looked at seem to require one. You noticed I said GSM here, CDMA users are lucky – they can get lat-long values from their `CellLocations` without calling a web API, but my carrier, AT&T is GSM/LTE, so I cannot get lat-long values from my `CellLocations`.

This brings me to the second set of APIs I am using for data collection: The telephony APIs, and in particular, `TelephonyManager` and `PhoneStateListener`. These are the APIs I am using to get and update cell tower data, which are identified by their cell ID. This also allows me to know when I need to update the list of neighboring cell towers, though I have never been able to get any neighboring towers on my Moto X. Thankfully, this is the only piece of missing data, so it shouldn't be a huge setback. However, this does not provide cell tower location or range information (unless you are on CDMA, as I mentioned earlier), so I use a `LocationListener` to get this information, along with a check of the accuracy attribute, to filter out the Wi-Fi locations. I also started implementing a fallback method to get a location online in case we can't get one through our `LocationListener`, but had to give it up after I couldn't find a service that didn't require an API key (it currently pings `localhost`, which causes it to silently fail).

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The last set of APIs I am using for data collection is the Wi-Fi networking APIs, and in particular, `WifiManager`. Unfortunately there is not a Listener class for changes to Wi-Fi, but since `LocationManager` uses Wi-Fi for some of its locations, `LocationListener` is usually good enough for catching changes to Wi-Fi connection state. Therefore, my `WifiInfoCommunicator` service scans for Wi-Fi changes every time a change in network location is detected. Granted, this may miss changes that happen when the device is disconnected from Wi-Fi, and not using it for locations, but it should catch changes to the Wi-Fi networks the device does connect to.

For exporting data, I chose to use Android's new Storage Access Framework and its built-in save dialogs. Unfortunately, this does have a side effect: Since this API was only introduced in Android 4.4, users on earlier Android versions cannot export data to CSV. Like the lack of a database in the app, this is something I could've fixed but simply didn't have the time to do so. Those who are running on Android 4.4 and above, however, will see an Android system save dialog that will allow them to save the exported CSV file not only to their device but also to their Google Drive account.

What makes this possible is the use of an `OutputStream` given by a `ContentResolver` in response to data from the `Intent.ACTION_CREATE_DOCUMENT` intent. The app does not actually create the file or upload the data to Google Drive, it merely creates a string with CSV data and sends the string's bytes to the `OutputStream`. This allows me, as an app developer, to focus on the format of the file and not navigating through the Android filesystem or dealing with cloud storage.

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Lastly, the interface makes use of **Fragments** and a shared root **Activity** that allows these three views to have the same look and feel and set of menus. The Fragments allow me, as an app developer to work on one data and map view and reuse them in multiple Activities, while the shared root Activity allows the Activities that contain the views to share a set of menus and, for the most part, act as if they were one Activity. Additionally, I made good use of styles in the layouts, so I could have an attractive appearance while keeping my layout files uncluttered.

## **Assumptions**

Compared to my last couple of projects, Project 3 makes relatively few assumptions, as it is designed to degrade gracefully under most circumstances. However, I was not able to account for everything, so there are some circumstances under which the app will either crash or suffer from loss of functionality.

Chief among these is my use of Storage Access Framework without a fallback for exporting data to CSV. This means that in order to export the data collected to CSV, the user must be running Android 4.4 or newer. The app can still collect data on earlier Android versions, it's just stuck in the app. Also, the app expects the device to have both cellular and Wi-Fi connectivity. If either is missing, the app will crash, as you can see if you run it in the emulator. Fortunately, both are stated as requirements in the manifest, so the app should not install under these circumstances.

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Additionally, the user must be running Android 4.0 or newer. This is due to the app's use of Fragments in its layout. Again, this requirement is stated in the manifest, so the app should not install on devices that do not run at least Android 4.0. Last, the app must not leave memory in order for it to collect data. This is due to the lack of a database, which I did not have time to build into the app. This is a harder assumption to enforce than others, due to Android's background process-killing nature. If I had more time, perhaps I could've built in a database and set up system-level listeners to reload my services on network changes in lieu of a permanent process, but I would not have been able to deliver that in time.

## **Problems and Challenges**

I have run into several problems through the course of making this app. Chief among them was my inability to find an API to look up locations of cell towers that did not require an API key. This meant that my list was lacking in locations of cell towers, since I was only able to use what the `LocationManager` and `LocationListener` would give me. Another problem had to deal with duplicates in my database. While I have cleaned out most of these from my tables, the CSV files contain plenty of duplicates in both the Cell Networks and Wi-Fi Networks table.

Additionally, during the implementation stage of this, I faced several issues, the chief being making the signal overlays semi-transparent and having them scale when the user zoomed in and out of the `MapView`. I eventually managed to pull this off, so these overlays should be a semi-accurate indicator of range regardless of which zoom level you are at.



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## **Conclusion**

All this said, I was able to create an app that collected the data and locations of cell and Wi-Fi networks (at least most of the time) and export them to a CSV spreadsheet. As a bonus, I added a MapView to display the user's location along with the locations of the networks discovered. Granted, there still are some bugs and issues here and there, but considering I was able to incorporate all the features needed (cell and Wi-Fi network collection, CSV export) and some extra features (in-app mapping) that were not required, I think I did a good job with this app.