Tech Note 11: Industrial Internet of Things: Conducting a Site Survey

By: Matt Crites w/ contributions from Donald Francis

What is a Site Survey:

The Industrial Internet of Things or IIoT has quickly become the standard for cost effective, reliable, and secure data transmission for monitoring and control of key industrial assets. LEC Inc has been at the forefront of this expansion and has become a leader in the design and deployment of secure networks, hardware and software technologies.

LEC's IIoT solution utilizes cellular to move data from the field to the "cloud" and, just as with traditional wireless communications technologies, cellular is susceptible to interference that could potentially temporarily prohibit data to be transmitted. These obstacles can include but are not limited to landscape, distance in relation to the nearest tower, material of the building, etc. All the forementioned could potentially weaken the overall received signal from a cellular tower regardless of chosen carrier. Without taking these potential obstacles into consideration, it could cause the cellular comms to be less than optimal. However, with the proper mechanisms, planning, and architecture along with the expertise provided from LEC, those comm risks can be mitigated. This document will break down and explain how to properly conduct a site survey.

Part 1: Towers and where to find them

Cellular is and will always be a shared medium however, LEC has partnered and has built out their own private network so sharing that bandwidth with hundreds of others has essentially been eliminated however LEC still must use the same towers that the carriers have stood up to provide coverage. Those towers usually follow a path along major roadways and highways and well as heavily populated areas since that is where a tremendous amount of usage comes from. The more rural or farther from those areas a cellular gateway is installed, could greatly affect how much of the overall radiated power from the cellular antenna reaches that gateway antenna. It is important to know where those towers are located, especially when using directional antennas.

1.1: LTE Signal and Signal Quality

Signal strength is measured differently, depending on the technology being used. 2G, 3G, and Wifi use RSSI to measure the strength of a received signal, measured in dBm. The higher the dBm displayed, the stronger the signal. For example, an RSSI of -75 dBm is considered a strong signal with a -60 dBm being even stronger. The lower the detected dBm, the weaker and more unreliable the signal is for data transfers. For example, a detected signal of -98 dBm is borderline poor with -110 dBm being no signal at all. In these situations, it is a good practice to move the antenna(s) to different positions or areas to try and improve the received signal. LTE does not use RSSI to measure signal. LTE uses Reference Signal Received Power (RSRP) to measure signal strength. RSRP is an RSSI type of measurement but, instead of measuring all received signals from all sources, it measures the average received power. With RSRP, a signal of -100 dBm is considered adequate signal where, with RSSI, it would have been unreliable for data transfers. Table 3 shows the RSRP ranges from excellent to poor.

LTE has a way to measure noise and signal quality. It uses Received Signal Reference Quality or RSRQ. RSRQ is displayed as a negative value in dBm and is used as a measure for tower hand off when more than one tower is detected. For example, if there are two LTE towers nearby, the RSRQ is calculated between the two towers and sent back to the serving cell to determine the handoff between the towers.

RF Conditions		RSRP (dBm)	RSRQ (dB)	SINR (dB)
	Excellent	>=-80	>=-10	>=20
	Good	-80 to -90	-10 to -15	13 to 20
	Mid Cell	-90 to -100	-15 to -20	0 to 13
	Cell Edge	<=-100	<-20	<=0

Table 1: RSRP signal levels

When reviewing signal strength, it is possible that having too strong of signal can cause just as much adverse effect on communication stability as too little signal. Communication and packet loss issues can be a direct result of having a too strong of signal. If experiencing such issues, it might be worth exploring adding a signal attenuator to the antenna. An attenuator can bring a signal's overall strength down by as much as 20 dB which can greatly improve stabilizing a cellular connection.

1.2: Tools

There are a number of websites that can show exactly where a particular carrier antenna is in relation to the address of the installation. These sites include but are not limited to:

- https://www.cellmapper.net
- http://www.cellreception.com/towers/
- http://www.cell2gps.com/

These sites can assist a service technician with how much signal could potentially be provided at a given site. Another piece to consider when choosing a location of an installation or antenna placement is cellular towers radiate signal directionally and could have blind spots. For example, in the below image, the cellular gateway is relatively close to the cellular tower however, the way the antenna is radiating its power, the cellular gateway is in that towers blind spot and may not be able to get adequate signal to maintain a consistent connection to the network.

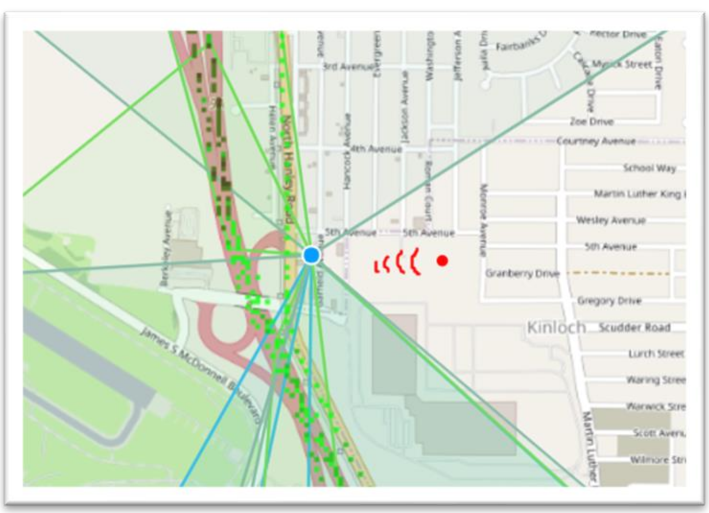


Image 1: Signal propagation

Using a cell phone is not the best tool to use for determining overall signal however if that is the only tool at your disposal, there are apps that can be utilized to assist with determining signal propagation and tower location. Once such as Network Cell Info Lite. This app will show a gauge with received signal as well as where the tower the phone is connected.

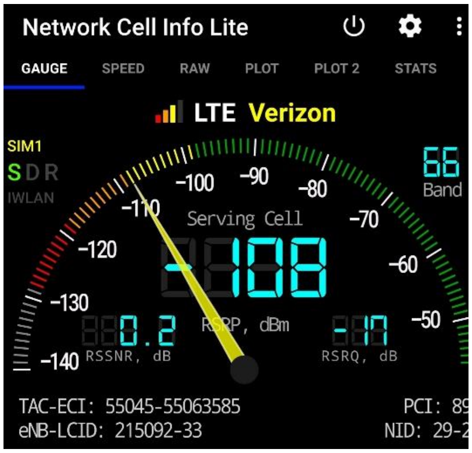


Image 2: Network Cell Info

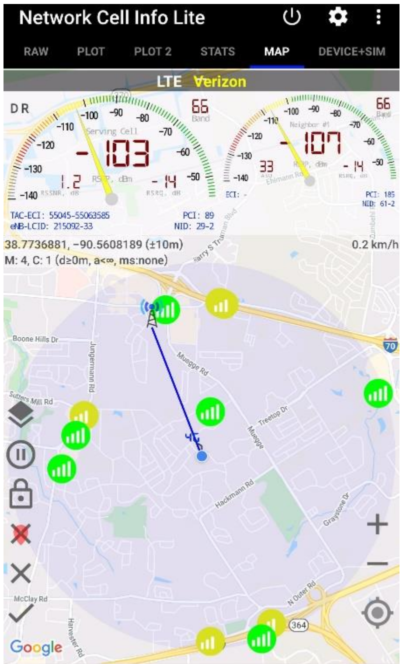


Image 3: Tower Connection

Part 2: Signal and the Environment

The environment plays a significant role in cellular. There are many facets that are beyond the control of a user that must be accounted for. Water, glass, hills, and mountains all affect the behavior of a signal. They can cause the signal to reflect or bounce off an object causing the signal to take a different path to the receiver than the original, arriving out of sync, causing data loss. Reflection can occur indoors as well. Metal is highly reflective and if a gateway is being placed onto a warehouse floor, reflection is almost guaranteed. This is where using multiple antennas can help with the multiple signal paths arriving at the cell router.

Walls are another environmental factor that must be considered especially if placing the cellular gateway in an interior wall of a building. The signal propagated from the tower has to go through these walls to get to the gateway. Every wall the signal must travel through will absorb some of that signal causing it to weaken by as little as -4 dBm for drywall and as much as -12 dBm for concrete.

Walls can also cause the signal to refract or bend in a slightly different angle from the original signal causing the signal to, again, take a different path. The signal can scatter in several different directions after coming in contact with rough surfaces or in especially dusty or sandy environments. Even the human body can have an effect on signal. Humans are made mostly of water. If there are a lot of people that are working near or around the gateway, their bodies can attenuate or weaken that signal.

Other equipment in and around the cell router must also be taken into account. Most machines give off EMI (Electro-magnetic interference). This interference is detected by the cell routers antennas and is viewed as “noise”. This noise can have a significant effect on a signal to the point of being completely unusable.

There are ways to help mitigate these issues so they will have less of an impact on performance and signal quality. Using a higher gain antenna is one such way. Another way is by adding height to the antenna, which can significantly improve the received signal when coupled with a low loss coax cable. Often times it can come down to simple trial and error. There might be areas on a plant floor or side of that building that are better suited for receiving signal than others. Sometimes simply moving the antenna to a different location can be the difference of improving overall signal.

2.1: Antenna Gain: dBi

By itself, an antenna does not generate any amount of power. In other words, when an antenna is disconnected, no milliwatts of power are being pushed out of it. An antenna's gain simply focuses the radiated RF into narrower patterns such that there appears to be more power coming from the antenna in the required direction. In other words, "gain" is a measure of how an antenna can effectively focus RF energy in a particular direction. A perfect antenna, called an isotropic antenna, will radiate power equally in all directions however no antenna can physically do that. What an antenna can do is decrease RF radiating from one direction and focus that energy in another direction, increasing the range in that direction.

For example, using a 9 dBi gain antenna vs. a 3 dBi gain antenna would add 6 dB to the link budget in each particular direction thus increasing the received signal. In figure 3, notice how the higher the gain, the narrower the signal becomes and the longer the range.

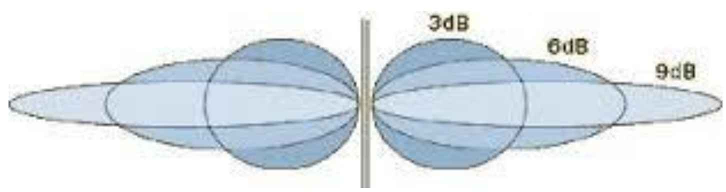


Image 4: Antenna Gain

There are other situations when antenna gain may be needed in an installation. One such example is when a cable is needed between the antenna port on the cell router and the antenna itself, especially if the antenna needs to be placed in a different location than the cell router like near an open window or outside of a building. In these cases, a low loss cable is needed. These cables adversely affect the signal by attenuating or weakening the signal as it travels down the cable. The longer the cable, the more the signal is attenuated. Adding a higher gain antenna can help offset that attenuation by adding additional dB to the link budget.

It is tempting to install a signal booster in low signal areas, as well. These can end up being more problematic because they not only amplify the signal but the noise as well and could cancel out any potential increase in signal.
Signal boosters can be an asset however only when interference or too high EMI is not the root cause of the poor signal quality.

2.2: Directional vs Omni-Directional Antennas

Most traditional antennas are omni-directional. In other words, they radiate RF in multiple directions in a 360-degree plane, as shown in figure 4. This way, no matter where you might be in a particular area, signal has a greater likelihood of reaching your host device. In most cases, omni-directional antennas will meet your installation needs however there will be times when a directional antenna may be a better choice. For example, suppose there is more than one cellular tower within a small geographic area. Due to using the omni-directional antenna, it's going to receive signal from both towers. This can be problematic if the cellular module keeps switching between the two as signal fluctuates over time.

In this case, using a directional antenna that can focus the RF by pointing towards one specific tower, signal from the second tower will no longer be detected. There are some caveats to consider when choosing this path. Using a direction antenna will mean, if that tower should have problems or become congested with users, the overall received signal will decrease significantly causing the cellular module to possibly disconnect from that tower altogether. With the omni-directional, the cellular module would scan for a stronger signal and connect to the other cellular tower.

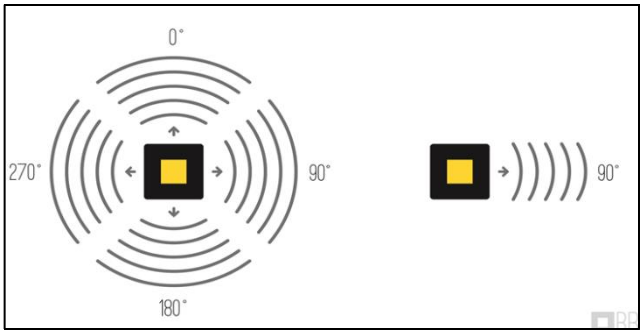


Figure 4: Omni-directional (left) vs Directional (right)

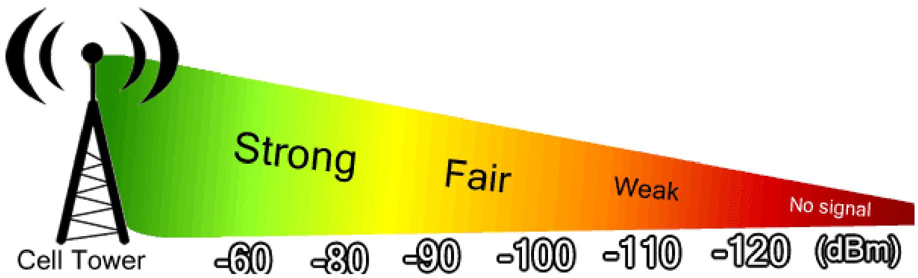
Part 3: Conducting a Site Survey

Completing a successful site survey can be done in multiple ways. The below outlines what LEC has determined to be best practices to gather the necessary information to ensure a stable connection can be maintained. No comms has a guarantee of 100% uptime since carriers perform routine tower maintenance that could have an impact on a cellular gateways ability to communicate with the network however by following the steps outlined below, it can greatly minimize as much down time as possible. LEC will assist with evaluating the results to ensure the best possible connection can be achieved.

3.1: Information Gathering

Step 1: Tower Location

The first and most important step when gathering information is tower location. Knowing where towers are located near a potential panel installation site is crucial. This information provides the installation technician with which direction to point the antenna, if using a directional, and, depending on distance, the coverage that can be expected. Is the tower nearby so coverage should be relatively strong or is the site on the edge of coverage? As mentioned earlier in this document, determine if dead zones are present. Simply because a cellular tower is in sight does not necessarily mean the tower is propagating signal in the direction of the site. Use the tools mentioned earlier to map out cell tower locations and the distance of each.



Step 2: Carrier Selection

After the towers in the area are mapped, which carrier appears to have the better coverage in the area? Avoid using carrier specific coverage maps. Nearly every major carrier's coverage map will look relatively the same, coast to coast coverage but that is not always the case. It all depends on where the site is located relative to the towers and how much power, EIRP, that tower is transmitting.

Step 3: Measuring Signal

There are several ways to measuring signal of a given site. The most ideal is to have a cellular gateway with the appropriate carrier on the ready and leave that device connected for a minimum of 24 hours. Most connection problems will manifest within that 24-hr time period. LEC can provide site survey panels that, one powered up at a site, will record signal fluctuations and plot them on a graph using iQ2.

If this option is not available, then using a cell phone can be used but it is not recommended. A cellular phone behaves much differently than a cellular gateway. The modules that communicate with the towers are different and it is not possible to test multiple carriers in a single location unless the technician conducting the survey is carrying two phones or two SIM cards.

A cellular phone can be used to determine tower locations of the carrier installed as illustrated in the Tools section of this guide. It may be necessary to turn on a cellular phone's "Field Test Mode". This mode will provide additional network related information than is not shown by default. Each manufacturer has a different method to get access to this mode:

For iPhone:

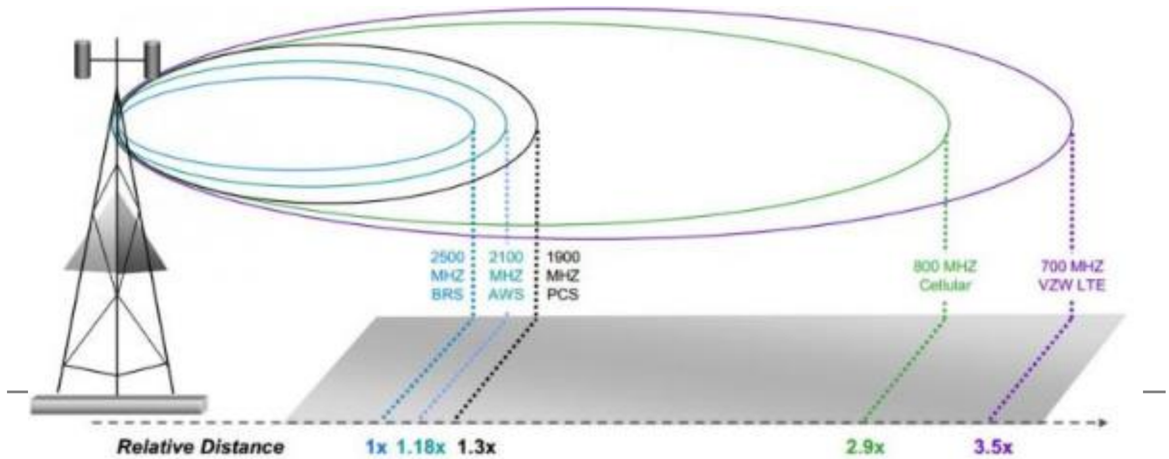
1. Go into Settings > Wifi to turn off Wifi, if using
2. Go into the Phone app and switch to the Keypad, as you would do to dial a phone number. Dial *3001#12345#* and press the Call button.

For Samsung/Android:

1. Go to Settings > About Phone
2. Status Information > SIM card status

When taking signal readings, move to the location where you want to take the reading, wait for 30 to 60 seconds for the signal readings to catch up, and then record the signal strength. Again, if a cellular phone is all that is available to record a baseline signal, it can be used but it is not recommended and could potentially have little impact on evaluating what to expect at any given site.

Band/Frequency plays a role in successful data transmissions as well. The higher frequencies will attenuate, or decay much more quickly than the lower frequencies so those frequencies are able to travel much further but are not as fast.



3.2: Evaluating Results

After all the above steps have been done, it is time to evaluate the results to make the best decision on antenna selection (omni vs directional) and carrier selection. The below chart outlines the signal evaluation:

From the image, the results can be evaluated as follows:

Excellent: -90 dBm on 4G or LTE network is considered excellent.
Good: -91 to -105 dBm on 4G/LTE
Fair: -106 to -110 dBm on 4G/ LTE
Poor: -111 to -119 dBm on 4G.
Dead Zone: -120 dBm is considered a dead zone and unreliable

LEC deems any signal higher than -105 dBm to be potentially problematic and could cause unstable communications. Just as with signal, distance relative to the nearest tower can also contribute to unstable communications, especially is very rural areas. The majority of cellular towers will be found within populated areas. The more rural and less populated an area is, the further away the nearest cellular tower may be. In this case, it will require the installation of a directional antenna and it could take some trial and error adjusting the antenna direction and height to ensure the best possible signal is achieved. It is recommended if the panel site is more than two miles away from the nearest tower, a directional antenna must be used.

Just like having a single tower nearby, having multiple towers in the same geographical area can also sometimes, but not often, problematic. The reason for this is because all towers emit a certain EIRP (Effective Isotropic Radiated Power) which refers to the amount of power the tower is using to transmit its signal. If using an omni-directional antenna and there are multiple towers within that site’s footprint, the cellular gateway may “tower hop” causing an unstable connection as well. In this case, it is recommended to use a directional antenna.

Conclusion

Conducting a successful site survey is a vital step to better ensure a panel installation runs smoothly well after the install has been completed. Locating nearby towers and recording signal levels will not only prevent unwanted communications issues but it will also help prevent unnecessary site visits. By simply following the guidelines listed throughout this document, can save considerable time and money trying to diagnose a communications problem. LEC has performed many successful site surveys and are here to assist.