NB-IoT:
The Need for Scanner Based Testing

ROHDE & SCHWARZ
APPLICATION BRIEF

NB-IoT, (Narrow Band Internet of Things), also known as Cat NB1, is a standard for connecting "things" to the internet through the cellular network. This is a standard focused on machine to machine communications. The range of applications are vast, with key applications including asset tracking, intrusion detection, utility meter reporting, smart parking areas, and home health care monitoring. This class of communications devices generally have low data volume, are not highly mobile, and not latency sensitive, but they can be mission critical. Most importantly, though, NB-IoT devices will likely be deployed in very large numbers.

NB-IoT is focused on optimizing the cellular link to massive numbers of fixed-location devices which generate infrequent, short communications. The technology is optimized for long device battery life and good in-building coverage.

What is NB-IoT?

NB-IoT is a narrow band Orthogonal Frequency Division Multiplexing (OFDM) signal compatible with current versions of LTE. While different enough to require its own standard, many of the terms, modulations, and signals are similar to those of LTE, though simplified.

NB-IoT has a 180 kHz wide carrier (one LTE Physical Resource Block) which contains 12 OFDM sub carriers and is preferably deployed in the 700, 800, or 900 MHz bands to assist with signal penetration in-building.

Since in many cases the RF spectrum is already occupied by cellular services, NB-IoT supports three different operational modes: In-band operation, guard-band operation, and stand-alone operation.

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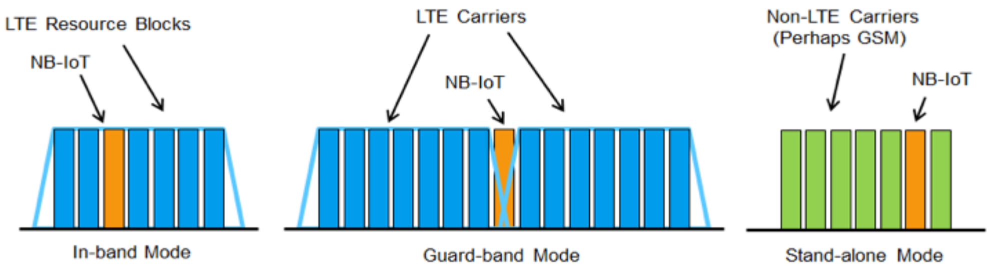

Figure 1: NB-IoT operation modes

In-band operation uses one physical resource block in an existing LTE carrier. This does not require any additional (expensive) frequency bands, and can likely be implemented with only a software upgrade to the eNodeB.

Guard band operation is also unlikely to require new RF spectrum, and allows the NB-IoT carrier to be broadcast in the already allocated LTE guard band.

Stand-alone operation works nicely if refarmed GSM spectrum is available, since NB-IoT carriers fit nicely into a GSM channel plan. That varies by country, city, and carrier, but the flexibility is there.

The Importance of NB-IoT

NB-IoT, when coupled with widespread cellular links and cloud services, is anticipated to have a large impact in many application areas. Specific areas that have received recent attention across many established and new markets include:

- Agriculture
  - Optimized cattle feeding
  - Optimized crop watering

- Health care/e-Health
  - Fitness trackers
  - Home health care tracking – early hospital release

- Safety and Security
  - Gas leakage alarms
  - Fire alarms and pumps
  - Intrusion alarms
  - Building management systems
  - Child tracking
  - Pet tracking

- Automotive
  - Smart parking spot locator – traffic reduction

- Logistics
  - Tracking shipping containers
  - General asset tracking
  - Rental bike tracking – theft and clutter reduction

- Smart City
  - Connected parking meters and street lamps
  - Smart garbage bins – optimized collection routes
  - Energy and Utilities
  - Smart Metering – collecting electricity, water and gas meter usage data

NB-IoT is anticipated to impact markets from agriculture to automotive.

NB-IoT Rollout Concerns

So we have a low data rate, highly reliable, signal that can be implemented using existing LTE network hardware. Not much of a planning issue, right? Well, there are some key causes for concern.

The NB-IoT concept is that a very large volume of battery powered low cost devices are deployed rapidly, without undue concern about the RF propagation conditions. Locations in basements, utility cabinets, and water meter enclosures are all considered usable. Expectations are that the battery life will approach 10 years. So we have high volume installations, poor signal propagation conditions, expectations of long battery life, and mission critical applications such as in-home health care or utility metering. What could go wrong?

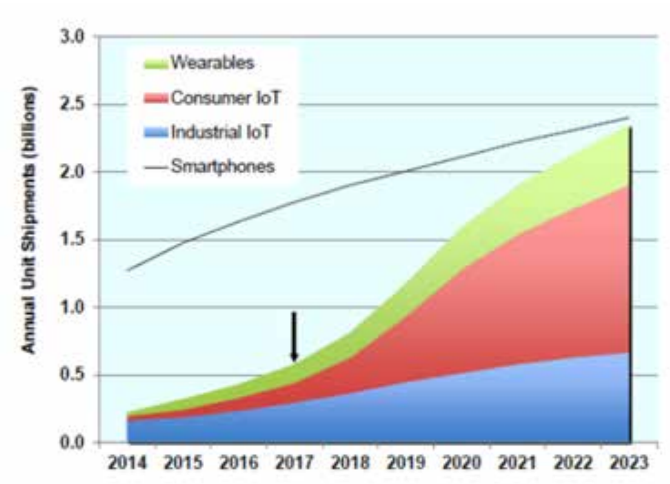

Figure 2: IoT take rate and projected growth (EE Times and the Lindsay Group, 2017)

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Installation Volume

Industry experts are using an ultimate installation volume number of 40 devices per household for their planning. (Ericsson, 2016) If we take a city such as San Jose, California, USA, with 300,000 households, that works out to about 12 million devices when complete to its full potential. This is for one city. That's not a rollout you want a high fault rate for, particularly since some of the more critical installations will require skilled labor with the (expensive) associated truck rolls. The IoT projected growth graph shows the current take-rate, with future projections. It's happening.

Curbside Installation Example

Here's an example of a utility converting to NB-IoT. In this case, water meters in Morgan Hill, CA, USA, were converted to NB-IoT reporting. You can see the small black antenna visible from the curbside, and the rugged environmental conditions experienced by the NB-IoT device, located under the water meter cover.

In this example, the NB-IoT device is mission critical. The water company will not get paid if the device cannot communicate to the cloud via NB-IoT. Any repair or replacement requires a truck roll, and skilled labor. However, most repairs will likely be of the “swap-it-out” variety as it is unlikely that the repair person is equipped to do any RF link analysis in the field. If there are persistent issues at particular locations, it’s likely that the network operator will be called in.

Figure 3: NB-IoT Water Meter Curbside Installation.

Deep-Building Installations

The extended link budget margins of NB-IoT will help a lot in deep-building applications. The path loss budget is specified at 164 dB, which is 22 dB more than LTE. Also, the NB-IoT signal is typically power boosted from 6 to 12 dB over the LTE carrier signal. This is the good news. The bad news is that this margin is intended to help with reaching locations deep inside buildings, and/or locations inside utility cabinets which may also be inside buildings. Then there is the issue of the effect of new energy efficiency standards for buildings. The British Regulator, Ofcom, did some research and testing on building entry loss for construction that meets new energy efficiency standards (Ofcom, 2014).

Their conclusion is that the exterior walls plus metalized glass and/or foil-shielded insulation can cause a 6 to 10 dB loss at right angles to a wall or thermally insulated window. As the angle of incidence goes up, the loss can increase to as much as 20 to 30 dB depending on the carrier frequency. That can eat up a 22 dB path loss margin quickly. Then there is the loss from internal walls, floors, and other architectural barriers to consider. An accurate propagation model of buildings in your coverage area will be quite helpful.

Crowded Spectrum

As we all know, the cellular spectrum is expensive, and as a result, crowded. Existing spectrum may need to be cleared, guard bands may be necessary, and in-fill LTE eNodeB’s may have been used for additional throughput (Densification) making adding a new service far from simple. Interactions between existing cellular services and NB-IoT will quite likely result in the need for a new network optimization effort.

NB-IoT rollouts have the potential to affect every customer, including business customers. The effects of this rollout on existing services and that of the existing services on NB-IoT should not be ignored.

Why Test?

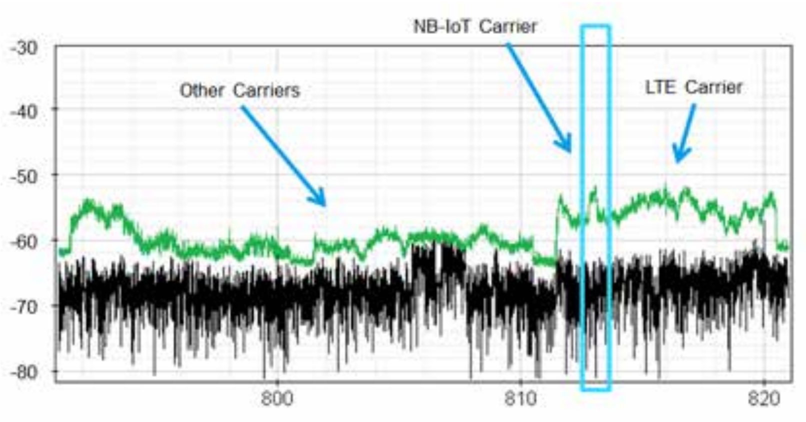
The very simplest test plan is to not test at all. Just install a $10 IoT device, assume it will find a network and move on. And in fact, many NB-IoT devices will be installed in exactly that manner, by consumers and non-RF savvy people. It is when the (many) devices do not work that the problems will start. Given the anticipated installation volume, deep-building locations, potential effects on existing services, and mission critical tasks, hoping that NB-IoT devices will function properly is not enough.

RF Scanners enable the creation of a valid coverage model, validate predicted coverage, simplify troubleshooting, and enable benchmarking.

RF Scanners provide frequency clearing, coverage, co-existence, troubleshooting, and benchmarking information. They enable the creation of a valid coverage model (which is particularly important in the highly variable deep-building installations), validate predicted coverage, simplify troubleshooting, and enable benchmarking. Let's take a look at these one at a time.

Frequency Clearing

When rolling out NB-IoT services in stand-alone or guard-band mode, it's quite important to ensure that the anticipated downlink and uplink frequencies are clear over the service area. Spectrum measurements, both in Spectrum and Spectrogram mode, can be invaluable in this task. With the addition of limit testing, trouble spots can be automatically flagged. Issues can be from either adjacent channel bleed over or from actually having a rogue carrier on the anticipated channel.



A more pervasive issue is in-band interference. Receivers can be de-sensitized by any RF signal that reaches their first mixer. Since the low cost NB-IoT receivers are not likely to have a pre-filter, a generally high noise floor on the downlink band can cause a loss of sensitivity of the NB-IoT device receiver. That can be a real issue when the device is in a location with high path loss.

Implementation when the NB-IoT signal is located within an LTE downlink signal is a bit more interesting and will be covered separately

Coverage Testing and Model Validation

Outdoor scanner based coverage testing is focused on signal strength and signal quality from the serving cell and the adjacent cells (Top N cells) versus location. The big new concern with NB-IoT is the in-building walk testing, in particular, the deep-building locations that NB-IoT is intended to serve. Devices in basements, metal equipment cabinets, and in other awkward locations are all meant to work.

There are quite a few NB-IoT scanner based coverage measurements, and each one has a specific purpose. They are measured per-serving-cell and each measurement set is geo-referenced. They focus on the sync signals (power, RSSI, and Signal Quality) and the full bandwidth measurements (power, RSSI, and Signal Quality).

These measurements can be used for propagation model calibration both indoors and outdoors, coverage validation, and for identifying areas of pollution or interference from other cellular technologies or faulty RF equipment.

In addition to the physical layer measurements, a scanner can demodulate the NB-IoT signal to display the level 3 setup information, specifically the information in the MIB (Master Information Block) and the SIB1 (System Information Block 1). This provides a wide variety of network configuration information that can help diagnose network setup issues.

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Co-Existence Testing

The cellular spectrum is crowded, and adding a new service to the existing services will affect both services. To find out how much and where these services are affected is the task of the scanner.

LTE and NB-IoT Simultaneous Testing

Let's talk about a common use case, NB-IoT implemented inside an LTE band. This may be implemented with nothing more than an eNodeB firmware upgrade, making it quite attractive from a financial standpoint.

As shown in the figure, NB-IoT's Signal to Interference plus Noise Ratio (SINR) can be affected by the LTE host signal, and also, the other way around. More importantly, if densification has been implemented, nearby cells may not be set up to avoid the NB-IoT carriers, and so degrade both signals.

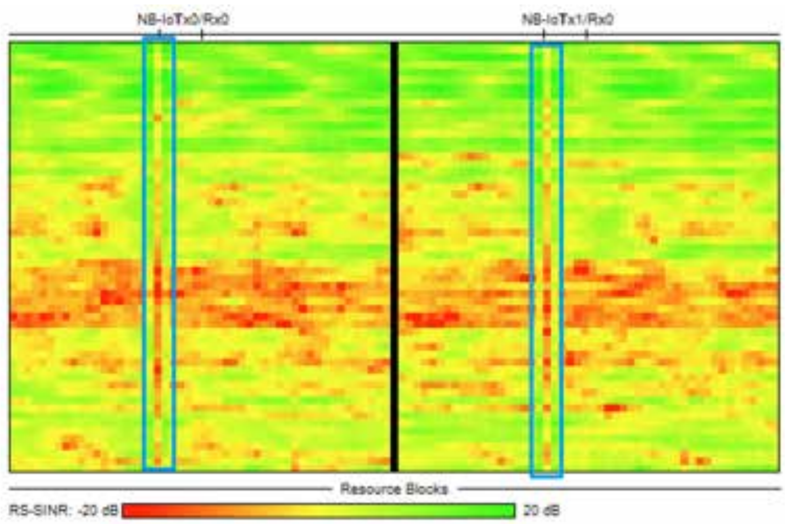

Figure 5: RS-SINR visualization of LTE with in-band NB-IoT.

NB-IoT Power Boost

The NB-IoT signal is normally power boosted compared to the LTE signal, to enable better coverage in difficult areas indoors. The power boost can be seen in the RF Power Scan (spectrum view) and measured in the LTE and NB-IoT Top N scans. This is an effective check on the eNodeB configuration and a clue when troubleshooting interactions between the two transmission setups.

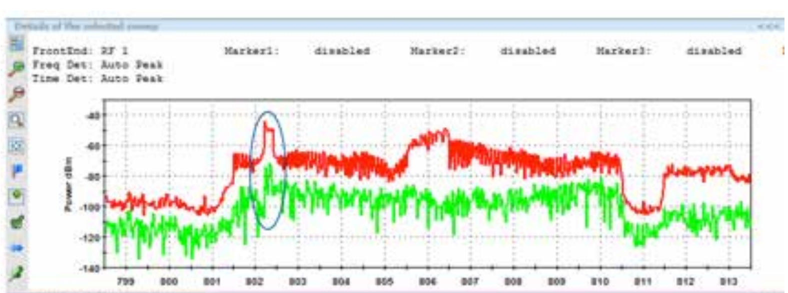

Figure 6: RF Power Scan view of NB-IoT Power Boost within an LTE signal.

GSM and NB-IoT Simultaneous Testing

There is a similar interaction between stand-alone NB-IoT, implemented into former GSM frequencies and any existing GSM carriers. In this case, the issue is adjacent channel power, either from the GSM signal interfering with the NB-IoT signal, or the NB-IoT signal interfering with the GSM signal. This can be spotted by the scanner when it is set up to scan GSM and NB-IoT in parallel. A typical scenario is when a geographic area with NB-IoT is adjacent to an area without NB-IoT. The high power levels typical of GSM lead to significant overlap, and that can result in lower CINR or SINR measurements in these boundary areas, particularly in the higher levels of high-rise buildings, where the strong GSM carriers have less path loss.

Troubleshooting and Benchmarking

When there is a QoS or network KPI issue, a scanner is a good first tool to assess the complete RF environment using the capabilities discussed earlier.

Pass/Fail thresholds allow automatic identification of trouble spot locations. In this case, they are identified by colored pins on an area map. This sort of graphical, location based, analysis greatly speeds up the hunt for issues by giving you a both a physical location and a good analysis of exactly the issue that you are facing. With these clues, resolving the problem will become much easier than without these clues.

Figure 7: Mapped display of detected problem spots along the drive test route.

Scanner measurements are passive, not active. They don't require an active network subscription, so they are not limited to a specific band or network. This makes it possible to measure signal parameters for multiple networks during one drive, or perhaps, one walk. Knowing how your signal compares to that of other network operators can assist greatly in network optimization, and help resolve configuration, pollution, interference, and many other issues.

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Conclusion

NB-IoT has a wide range of applications for agriculture, health care, security, safety, automotive, logistics, smart cities, and utilities. However, key concerns are projected installation volumes, deep-building installations with the associated path loss, and the effects on existing services in the crowded RF spectrum. Given the projected installation volume and mission critical applications, it is important to plan properly both for rollouts and for the necessary network optimization and troubleshooting.

NB-IoT scanner measurements, when supported with ROMES4 software, provide a way to see what is happening in your coverage area, both in your spectrum and nearby. Scanners allow you to analyze coverage and co-existence issues, as well as troubleshoot problems and benchmark both your signals and other provider's signals. If you can't see it, you can't fix it, and a scanner is the fundamental window on what is happening in your spectrum.

More Information

For more detailed information on the use of scanners to test and optimize NB-IoT services, the R&S Application Note titled "NB-IoT measurements with R&S®TSMx scanner" provides an in-depth testing discussion for NB-IoT signals.

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