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NARROWBAND IOT DELIVERS
INSIGHTS FROM THE LARGEST NB-IOT INDOOR MEASUREMENT CAMPAIGN

Whitepaper, January 2019

Abstract

Deutsche Telekom's NarrowBand IoT (NB-IoT) network has proven its capabilities in the largest NB-IoT indoor measurement campaign conducted so far, achieving a 100 % attach rate above ground and a 95 % attach rate in basements. This meets and even exceeds the expectations for NB-IoT to perform better than existing cellular technologies, such as 2G / 3G / 4G. Once attached to the network, data transmission for each measurement cycle was possible in nearly all cases (99.75 %).

The campaign was initiated by Deutsche Telekom and independently conducted by P3 Communications GmbH in cooperation with ista International GmbH, which provided access to the measurement locations. Measurements were done for about 500 position pairs in and around 60 apartments. One position pair is defined as one outdoor position and one corresponding indoor position. The measurement results prove the capability of NB-IoT in a typical real-world usage scenario on Deutsche Telekom's live network.

Introduction

NarrowBand IoT (NB-IoT) is a new cellular technology based on the global 3GPP standard, operated within licensed spectrum and specifically designed for the Internet of Things (IoT). NB-IoT has low power and low cost requirements and achieves up to 20 dB better indoor coverage compared to 2G. A typical use case is remote reading of heat cost allocators, where requirements on bandwidth are low and deep indoor penetration, operating costs and battery life are critical. Deutsche Telekom and ista International, one of the world's leading companies for improving energy efficiency in the real estate, have entered a technology partnership to gauge the capabilites of NarrowBand IoT.

ista's main field of business is the submetering of energy and water. With NB-IoT, each meter would gain direct access to the network, whereas currently a gateway is required to collect and transmit the data of nearby meters. For the measurements Deutsche Telekom provided its live NB-IoT network while ista provided access to measurement locations. The measurements were independently conducted by P3 communications GmbH. The aim was to test NB-IoT from an end-to-end perspective to determine indoor path loss and also to verify the similarity of radio propagation characteristics of NB-IoT and LTE.

Figure 1: Measurement setup showing the scanner antenna (on top) and the housing containing the antenna feeding the Quectel BG96 module

Methodology and setup

Two measurement devices were used simultaneously for data collection: One using an NB-IoT module for connecting to the network and another one using a scanner for passively assessing signal quality. The measurement setup is shown in Figure 1. On top of the metal plate the scanner antenna is mounted. The white housing on the front plate contains the antenna of the NB-IoT device. Both antennas are connected to the actual scanner and NB-IoT device, respectively. These are placed in a hard-top case which also contains the batteries. The purpose and function of the devices is described as follows:

1. **The NB-IoT device for active measurements:** A Quectel BG96 module on a development board. The device attaches to the network and transmits UDP packets to a server and receives them back from the server. The device allows tracing and thus determining attaches, coverage extension level, data transfers, round trip time, RSRP[1] and CINR[2] for the connected cell. The device was connected to an external antenna in a typical heat cost allocator housing (white housing as in Figure 1).

2. **The scanner for passive signal analysis:** A Rohde & Schwarz TSME scanner was employed for passive measurements of Deutsche Telekom's NB-IoT and LTE900 signals (Band 8). The scanner can be used to measure signal strength and interference levels and thus was deployed here to measure the top five received signals (in terms of signal power) from different cells. The scanner was connected to a vertically positioned rod antenna (on top of the metal plate as in Figure 1).

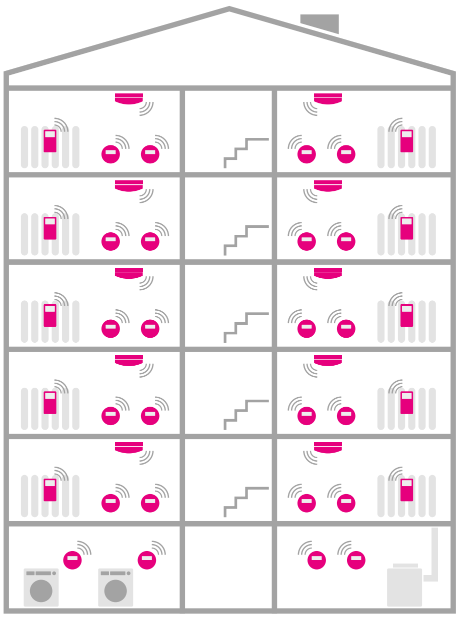

Figure 2: Measurements were done on several levels above ground and in basements

[1] RSRP: Reference Signal Received Power
[2] CINR: Carrier to Interference and Noise Ratio

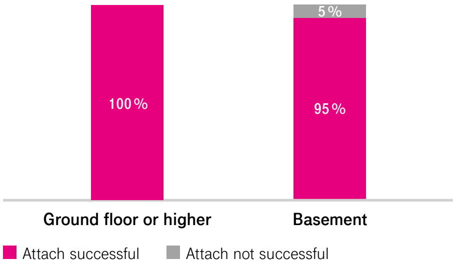

Figure 3: Indoor attach rate above and below ground

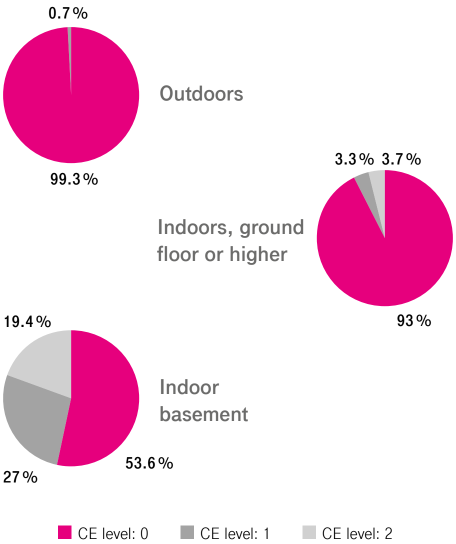

Figure 4: Distribution of CE levels outdoors, indoors above ground and indoors below ground level

CE level	Median attach duration [s]	P95 attach duration [s]
CE level 0	4.5 s	15.3 s
CE level 1	5.6 s	29.4 s
CE level 2	19.0 s	160.0 s

Table 1: **Attach duration depends on CE level**

CE level	Median RTT [s]	P95 RTT [s]
CE level 0	2,64 s	8.45 s
CE level 1	3.19 s	11.42 s
CE level 2	8.54 s	30.79 s

Table 2: **Round trip time increases with CE level**

[3] Median means half of the samples are higher and the other half is lower than the median value.

Both antennas were placed on metal plates to emulate usage near metallic radiators, a setup found in real deployments of heat cost allocators, which are placed on radiators. This setup potentially lowers reception and transmission performance, which happens often in real case scenarios. The measurement is stationary and the duration is 5 minutes per location.

Measurements were performed in over 500 position pairs in and around 60 apartments in the Cologne / Bonn area in Germany in May and June 2018. They were done inside and in front of buildings. The buildings were chosen to represent a typical profile regarding location (urban, suburban and rural), size and materials (brick, steel, glass, etc.). To estimate the path loss of radio propagation into buildings, each position pair consists of an inside and an outside measurement point. The location of the outside measurement point is chosen such that it sits between the base station and the indoor measurement point. At both points the device must be attached to the same cell in order to generate a valid position pair. Outside measurements were always conducted on ground level, whereas indoor measurements were conducted on several levels, including basements at level -1 or even -2, cp. Figure 2.

Main results

On ground floor or higher, a perfect **attach rate** of 100 % was observed. In the basements, attach was successful for 95 % of the measurements (cp. Figure 3). When attached, data transmission was possible for almost all measurements (99.75 %). While the measurement time was limited to 5 minutes, it can be noted that longer measurements may have likely led to even better results as devices may eventually be able to attach successfully after more than 5 minutes. Practically this means NB-IoT offers the highest indoor reachability compared to other existing mobile radio technologies.

Path loss is estimated as the median[3] of outside minus inside signal strength for each position pair. Path loss for LTE900 and NB-IoT is similar, as is to be expected because they operate in the same frequency band. This further underlines that existing propagation models for LTE900 can be used for estimating NB-IoT signal propagation. Path loss by height / level yields a statistical distribution. Results in the basement show the highest loss, as to be expected, with a median path loss of about 25 dB. On the ground floor, median path loss was 18 dB, on higher floors it was even less. These results allow much better prediction models than usual, where fixed values for any indoor environment are used.

A main feature of NB-IoT is **coverage extension (CE)**, which supports a base level (CE level 0) and two coverage extension levels (CE 1 levels and CE 2). CE levels are chosen by the network based on signal conditions (RSRP[1] and CINR[2]). One measure to improve coverage is increasing the number of repetitions in the uplink and downlink. The distribution of coverage extension levels is shown in Figure 4. Outside of buildings, practically no coverage extension is required. Indoors on ground floor or higher, for 93 % of measurements still no coverage extension is required. When measuring indoors in the basement, however, CE level 1 is used 27 % of the time and CE level 2 is used 19 % of the time. CE levels 1 and 2 require more energy to transmit signals. Still, the results show that even in unfavorable conditions long battery lifetimes can be expected.

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About the companies involved

Deutsche Telekom is one of the world's leading integrated telecommunications companies, which provides fixed-network / broadband, mobile communications, Internet and IPTV products and services for consumers, and information and communication technology solutions for business and corporate customers.

ista International is one of the world's leading companies providing energy management services for greater energy efficiency in buildings. ista specializes in the recording, billing, visualization and management of heat and water in 24 countries worldwide.

P3 Communications GmbH offers worldwide management consulting and engineering solutions, independent testing services, project management, strategic consulting and technology consulting.

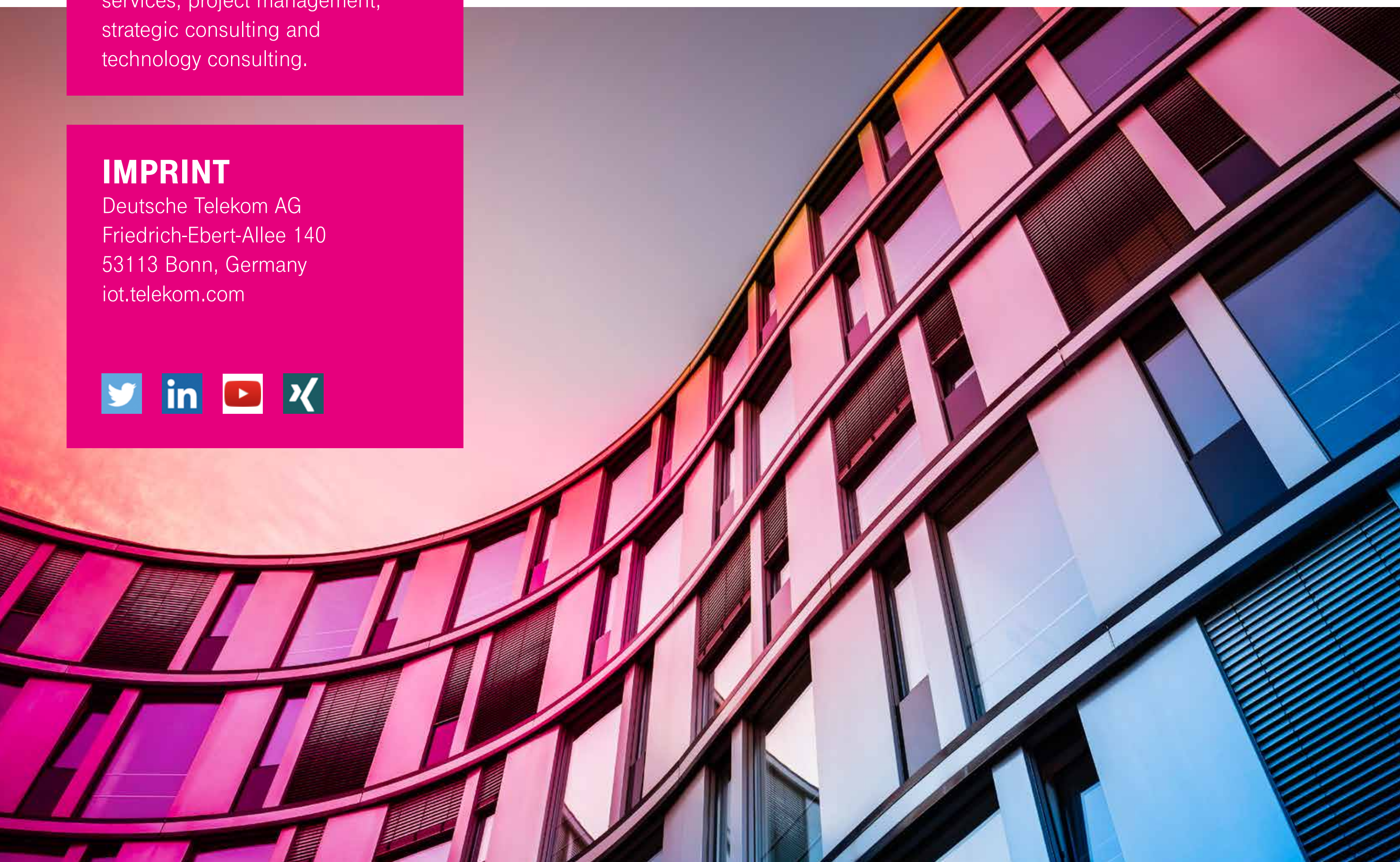
The median **attach duration**[4] depends on the CE level, as shown in Table 1. A new attach is done for each measurement. The median attach duration for CE level 0 and CE level 1 is similar, around 5 s. For CE level 2, the median attach duration increases to 19 s. The P95[5] attach shows that sometimes the attach takes quite long, particularly in coverage extension level 2.

The **Round Trip Time (RTT)**[6] is shown in Table 2. RTT is the time between sending and again receiving a packet, so it is influenced by uplink and downlink channel conditions. The median RTT for CE levels 0 and 1 is a few seconds. A large gap can be observed between CE levels 1 and 2, when the number of repetitions is increased severalfold. For all CE levels, there are samples for which RTT is much longer than the median RRT. However, on overall NB-IoT still works in bad radio conditions, including cell interference. Moreover, shorter RTT and attach durations would only have very limited positive effects in practical usage scenarios.

Conclusion and outlook

The largest NB-IoT indoor measurement campaign yet has proven the effectiveness of NarrowBand IoT on Deutsche Telekom's live network. NB-IoT is already performing well. More devices with improved radio characteristics will be seen and further optimizations are expected to make the NB-IoT network performance even better. With the rollout of NB-IoT proceeding at a fast pace and more and more chipsets, modules and devices reaching market maturity, it is now the right time for companies to develop their NB-IoT solutions in order to profit from this technology. NarrowBand IoT stands out within the IoT ecosystem as secure and reliable communication medium for various use cases. The technology is here to stay – and it will give the IoT industry a vital boost.

[4] Attach duration: Duration from first Attach Request message to first Activate Default EPS Bearer Context Accept or Attach Complete message.
[5] P95 means that for 95 % of samples, the attach duration is below the stated value and for 5 % of samples it is higher.
[6] Round Trip Time (RTT): Average time for 64 byte payload between packet upload to the server and subsequent download from the server, out of ten uploads / downloads per measurement position.



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