



Bluetooth 5 - Real Life Test Report

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Introduction

This whitepaper contains information about the new Bluetooth 5 wireless technology and about testing the operating range in real life. The report includes following information:

- How Bluetooth 5 boosts the wireless connection operating range
- Tools to measure the operating range
- Demonstration of how the operation range was tested
- Report of the results achieved

At first, the background for Bluetooth 5 features, testing tools and methods are explained. The measurements in different environments are described. In the end of the document, the results, subjects for further discussion as well as the summary of the Bluetooth 5 test findings, are concluded.



Background

Bluetooth 5.0 specification was released in December 2016. The main new features are marketed to quadruple the range, double the speed and increase data broadcasting capacity by 800% compared to BT4. These are separate, non-simultaneous features, i.e. you don't get double rate over long range. However, Bluetooth should now be on a whole new level. And to be precise, all the new stuff is about Bluetooth Low Energy that you can run on coin cell battery. Classic Bluetooth stays as it used to be.

Especially the Long Range (Coded PHY, 500/125 kb/s) mode as range improvement is essential for many applications like asset tracking. To test this new feature, Nordic Semiconductor's nRF52840 and Texas Instruments' CC2640R2 were used. The intention was not really to compare Nordic and TI kits. However, some practical issues of the kits are discussed.

Development Kits

Both Nordic and TI kits have ARM Cortex processor, flash memory for the program code, couple of interfaces like micro-USB for powering, programming and monitoring. Buttons and LEDs are for direct human interfacing, which is particularly useful when board is run standalone. To enable standalone operation, Nordic kit has a coin cell battery holder, while a handy developer needs to implement one in the TI kit.

Bluetooth 5 main features:

- Quadrupled range
- Doubled speed
- Increased data broadcasting capacity by 800% compared to BT4

Both manufacturers offer a set of example codes that support – to varying extent – Bluetooth 5 features. The example codes are very practical as they may be used for testing as such and even as a basis for prototyping. Full usage of the examples requires installing IDE tools, picking up the desired codes and also making modifications into the code. Time must be reserved to get things running if the environment is not familiar. Especially in Nordic case one should be careful not to have mismatches between the version of the example codes, the libraries, soft device or hardware. TI is somewhat easier because Code Composer Studio's Resource Explorer allows safe selection of software pieces that fit with the hardware. Anyway, both manufacturers have a developer forum where you can find a lot of information and there is reasonably fast support that responds to your questions.

Bluetooth 5 Features

Both Nordic and TI implement 1M (1 Megabits per second), 2M and Long Range modes (where is the 800% better broadcast?). The availability of the modes varies per example. For instance, Long Range mode can usually be entered only after 1M setup, i.e. there is no Long Range advertising or scanning available in all Bluetooth 5 examples. This is not too handy when testing the operating range in open spaces – after disconnecting you may need to walk back some hundreds of meters to get the connection up again.

Both manufacturers' examples contain a simple throughput test, monitoring of the signal strength (you may need to add it manually in some examples), UART character transfer etc. For testing the Long Range mode in full, Nordic has one example setup that allows advertising, scanning and link monitoring all using the Long Range mode.

While the Long Range mode is about repeating physical layer symbols and increasing receiver sensitivity, the range is also affected by the transmission power. Higher output power of 20 dBm (100 mW) is allowed for Bluetooth 5 devices, taking into account the regional regulations. However, the kits seem to not fully implement this advantage. Nordic informed that 8 dBm is the maximum with nRF52840, and TI's CC2640R2 has a limit of 5 dBm. These values were used in all tests. Anyway, 20 dBm transmission power barely makes sense with a coin cell battery radio so the values of Nordic and TI are practical.

Some practicalities faced:

- Long Range advertising and scanning were implemented only in part of the Long Range example codes
- 7 dBm lower sensitivity in Nordic nRF52840 (to be fixed)
- Limited output power (Nordic: 8 dBm, TI: 5 dBm)

Measurements

Manufacturer References

Nordic demonstrates about 770-meter Line-of-Sight (LoS) range in their [YouTube video](#). They seem to use 9 dBm output power, one dBm more than their own instructions allow. The RSSI values stay above -90 dBm.

TI has similar [video](#), but they get into awesome range of 1,5 km, while showing RSSI values about the same. It's not sure how well those results are comparable, but both are surely exciting and tempting to make your own tests. Bluetooth Low Energy used to be considered as a radio of "personal area network", so it's fun to see how large the personal area is nowadays – how far you get with a coin cell battery and standard radio technology.

Long Range Test Environments

The Long Range mode was tested in different environments to compare the operating mode. The test environments included following:

CONCRETE BUILDINGS:

through floors, walls, in a staircase as well as around a building.

OPEN SURROUNDINGS:

road surrounded by forest, a park, a field, and two lakes.

A battery-driven standalone board was set in a fixed position and the other one was moved around together with a laptop computer. The link quality was observed as RSSI values measured by the moving board. Both 1M and Long Range mode were used in the tests. The given maximum transmission power values were applied. Nothing was done for the RF, the PCB antennas of the kits were used as such.

Test arrangements are shown in videos which you can find on our YouTube channel:

- Testing BT5: Building <https://youtu.be/RACaZ0siok>
- Testing BT5: Watch Tower <https://youtu.be/lo5v7gUA3bc>
- Testing BT5: Lake <https://youtu.be/WgUkxDrDtxw>
- Testing BT5: Summary <https://youtu.be/zlCFMbqdPp0>

1. Staircase, Floors and around Building

The chosen staircase in a concrete industrial building has undivided airspace, but no direct line of sight (LoS) between the floors. Concrete buildings are known to be hard environments for radios operating on 2.4 GHz frequency band. In addition, it appeared soon that Nordic kit had an issue with receiving sensitivity. Link dropped in about -96 dBm although the board should provide -103 dBm sensitivity. Nordic informed that this will be fixed by their new soft device release (which wasn't available as of this writing). TI's kit appeared to get down to -103 dBm as expected. Both kits kept 1M link alive from floor 1 to floor 4, while Long Range mode gave just one or two more floors.



In another test (TI's kit) out of the staircase, without chance for such reflecting paths, Long Range mode penetrated quite reliably three floors. Clearly Bluetooth still has limitations to conquer buildings – the new Bluetooth Mesh is likely needed in many use cases.

Some tests were also done around a building. The chosen blockhouse was L-shaped, both wings about 50 meters long. Thanks to reflections from neighbouring buildings, TI's kit kept 1M link alive far behind the first corner, but the link died behind the next corner (opposite side of the building). However, Long Range mode did survive the walk around the whole building.

2. Watch Tower

In this test, the target was to get more range and Nordic's standalone kit was kept on the top of a local watch tower while the other one was moved along a road leading to the tower. The road gives almost 250-meter LoS before it slightly turns into forest.

Nordic's 1M worked about 250 meters and Long Range mode about 350 meters. Such range allows for example broadcasting advertisements from the Tower cafeteria over the parking area along the road. However, there was no real gain for lifting the Bluetooth broadcaster up to the tower since majority of people moved only along the road on one side of the tower. A broadcaster on the main entrance works well enough in such case.



3. Long Park

The next test was made in a long park. Full LoS was available about 400 meters before the alley of trees starts to bend. The standalone board was mounted in roof antenna of a car. TI's 1M carried almost 400 meters, Long Range about 550 meters, before disconnecting. Nordic's numbers were correspondingly 350 and 550 meters. The result was pretty good, yet still far below the distances seen in the manufacturers' videos.



4. Lake

The final tests were made on the widest and flattest open surface in central Finland – a still lake. The standalone board was embedded in a buoy. The buoy kept the antenna about 20 cm above water surface. 1M mode gave the best results so far, the Nordic kit's link was alive still at 400 meters distance on a small lake. Actually, the first lake was too small for testing the Long Range mode in such conditions.

The larger the lake is, the more easily there are waves. The waves were about 10 cm high (wind about 4 m/s) and TI's Long Range link stayed alive only up to 450 meters. Another day the lake was almost still and both kits were tested. This time the boards were lifted somewhat higher; 1.5 m on the shore and about 1 m in the boat. TI's Long Range flew this time about 650 m and Nordic's almost 750 m!



The Results

There are already couple of manufacturers and tools to get yourself familiar with the new Bluetooth 5 technology. In these tests, the development kits provided by Nordic Semiconductor and Texas Instruments were used. The key findings of testing the new Long Range mode and reasonably high transmission power in real life includes following:

BUILDINGS INSIDE

- 1M mode 1-2 through floors, Long Range mode through 3 floors.

BUILDINGS OUTSIDE

- 1M behind one corner, Long Range mode around the building.

PARKS & OTHER SEMI-OPEN SPACES

- 1M ca. 250-350m, Long Range mode ca. 350-500m.

STILL LAKE

- Long Range carries over 500m (up to 750m in our tests).

Things to keep in mind in general:

- Even if the operating range is generally longer, it still heavily depends on the environment
- The Long Range mode applies only to very low bitrate applications
- Power consumption per bit of the Long Range mode is higher due to repeating symbols (radio on longer time)
- The transmission power has effect on both operating range and energy budget

Conclusion

The new Long Range mode together with relaxed transmission power limit enable clearly extended operating range for Bluetooth LE. This is likely to increase the number of suitable applications and environments to use Bluetooth LE. There seems no doubt the Long Range mode, along with other Bluetooth 5 features, will become commonly adopted in mobile phones, pads and computers, like BT4/4.2 already did.