Energy Estimate for Cellular Connection

White Paper

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Contents

Revision history

Date	Description
2024-01-15	Editorial updates
2023-03-23	First release

1 Introduction

The Nordic-proprietary **`%CONEVAL`** *AT command* requests the modem for information about the cell and current *Long-Term Evolution (LTE)* radio link quality. It also requests for an estimate of the probability of energy efficient transmission. The response is given as an energy estimate value. An application can use the energy estimate value to analyze the probability of energy efficiency in an upcoming data connection.

The connection evaluation is the most useful in cases where the application data that is going to be sent is not time-critical and the sending can be delayed, or even dropped, if the evaluation response indicates an increased or very high risk of poor energy efficiency.

Since the connection evaluation consumes a small amount of energy, it should be used only when there is a need to set up a radio connection for the device to send application data. The amount of energy that the connection evaluation consumes is insignificant compared to the amount of energy consumed when establishing a connection and transmitting data in poor radio conditions.

The use of connection evaluation can be beneficial in many different types of environments. Radio conditions can be equally poor indoors and outdoors as well as in rural and urban areas, and the conditions can vary in all environments even with fixed deployments. For example, a device can be permanently placed in a location with poor radio coverage, such as a basement. The application logic might include occasionally establishing a connection for critical data transmission. In such case, the device would likely not benefit from connection evaluation, and some energy could be saved by not using it at all.

For more information on the **`%CONEVAL`** command and other response values, see Evaluating connection parameters %CONEVAL in nRF9160 AT Commands or nRF91x1 Cellular AT Commands.

2 Energy estimate value

The energy estimate values range from 5 to 9. The values are relative and cannot be converted into exact energy consumption values. The same energy estimate can mean different energy consumption levels in different networks, but it is comparable in a network when the network configuration stays the same.

The actual energy consumption per energy estimate value depends on the network. Operators configure differently the parameters that the networks use in data transmission, for example in repetitions, resource allocation, *Discontinuous Reception (DRX)*, and connection release. Network parameters that are not known to the device can lead to different current consumption averages and connection durations in different networks. Therefore, it is not possible to calculate how much energy is going to be drained from the battery in an upcoming data connection based on the energy estimate value alone.

The energy estimate value is based on the current radio conditions. Because radio conditions can change rapidly in mobility use cases, the energy estimate depicts the following data connection most accurately in static or slow-moving mobility, such as pedestrian, use cases.

The energy estimate values have the following definitions:

<energy_estimate>

Estimated energy efficiency of data transmission in different radio conditions. A higher value means better energy efficiency.

5 – Bad conditions. Difficulties in setting up connections. Maximum number of repetitions might be needed for data.

6 – Poor conditions. Setting up a connection might require retries and a higher number of repetitions for data.

7 – Normal conditions for cellular *Internet of Things (IoT)* device. No repetitions for data or only a few repetitions in the worst case.

8 – Good conditions. Possibly very good conditions for small amounts of data.

9 – Excellent conditions. Efficient data transfer estimated also for larger amounts of data.

2.1 Pedestrian use case

Live energy consumption measurements show that due to different configurations during data connections, the actual energy consumption can vary between networks even though the energy estimate is the same.

Graphs Figure 1: Live test result for Operator A on page 6 and Figure 2: Live test result for Operator B on page 6 show the results of energy consumption measurements performed for two operators in the same geographical area using *LTE-M* network. The graphs show also the corresponding energy estimate values from `%CONEVAL` responses.

Notes for the following graphs:

- X-axis: Energy estimate value.
- Y-axis: Energy consumption where the average of energy estimate value 7 is normalized to be 1.
- Blue curve: Average of energy consumption per energy estimate value.
- Red bars: Standard deviation from the energy consumption average per energy estimate value.

Note: The actual energy consumption that corresponds to the normalized value 1 in energy estimate 7 is not comparable between Operator A and Operator B.

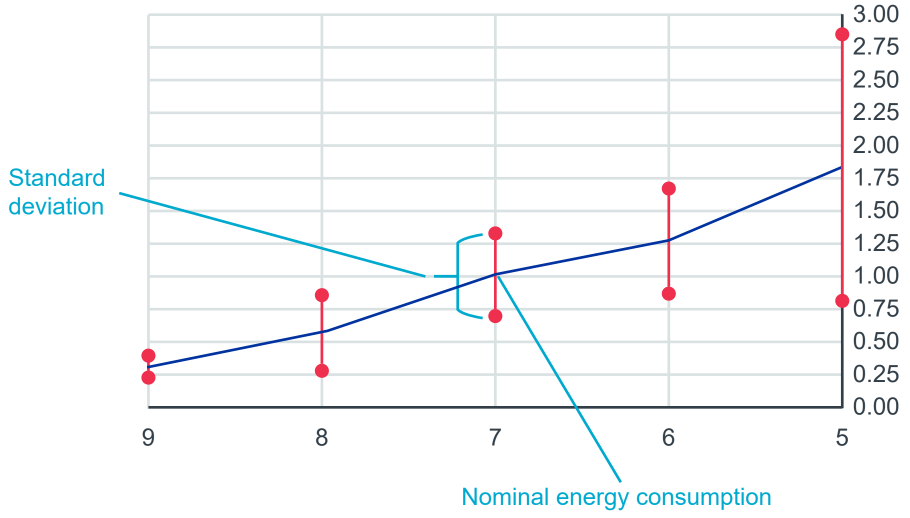

Figure 1: Live test result for Operator A

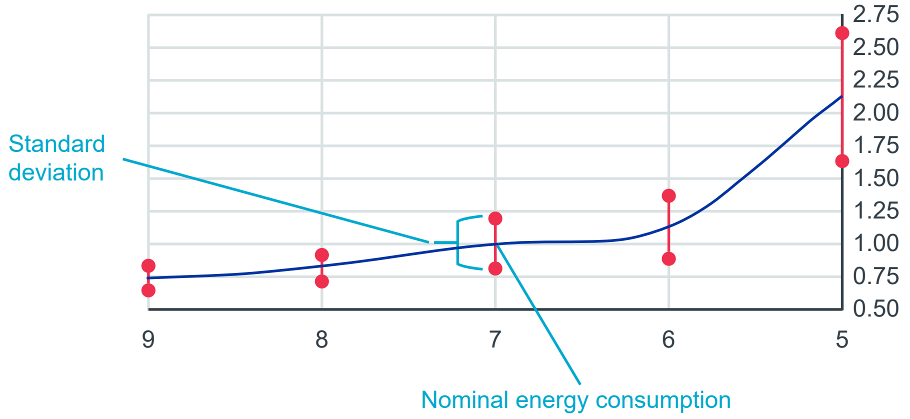

Figure 2: Live test result for Operator B

Figure 1: Live test result for Operator A on page 6 and Figure 2: Live test result for Operator B on page 6 indicate that the average duration of a connection was 17–21 seconds for Operator A and 5–8 seconds for Operator B. The tests show that although an equal amount of data was transmitted, the duration of the average connection was much longer with Operator A. A longer connection duration means that the absolute energy consumption was higher for Operator A also when the same energy estimate values were returned for Operator A and Operator B in **`%CONEVAL`** responses. Current consumption is always higher in RRC Connected mode than in RRC Idle mode even when there is no data transmission.

The energy estimate value 6 indicates a risk of increased energy consumption whereas the energy estimate value 5 indicates a significant risk of high energy consumption. The large standard deviation of the energy estimate value 5 indicates the unpredictability of the expected energy consumption. The test results show that standard deviation is smaller in better radio conditions, which might be important in longer data sessions.

If the energy estimate value is 5, it is recommended to avoid transmitting data with devices that have issues with power consumption or with *LTE*'s peak power levels. The nominal energy estimate value 7 is the most common value to be expected in a live environment. The nominal value is suitable for generic cellular *IoT* use cases, for example, short data transmission.

The duration of a data connection can be optimized with the *Release Assistance Indication (RAI)* feature. For more information, see Connection-related features on page 9 and Release assistance indication %RAI in nRF9160 AT Commands or nRF91x1 Cellular AT Commands.

For information on the test setup used for the pedestrian use case measurements, see Appendix on page 10.

2.2 Environment temperature use case

Environment temperature has an effect on energy consumption. The energy estimate value does not take environment temperature into consideration. This can be noted when optimizing energy consumption using the `%CONEVAL` service.

Graph Figure 3: Temperature's impact on energy consumption and energy estimate value on page 7 shows temperature's effect on energy consumption in an *LTE-M* network and the energy estimate values from `%CONEVAL` responses. The measurements were done with a Rohde & Schwarz CMW500 LTE protocol tester and temperature chamber. SMS was used as test data. One SMS consists of two transmissions and two receptions: the short message itself (< 200 bytes) and the needed ACKs in both uplink and downlink. This means that the transmission characteristics for an SMS are the same as for any similar amount of normal data exchange.

Notes for the following graph:

- X-axis: Energy estimate value.
- Y-axis: Energy consumption where the average of energy estimate value 7 in 25°C is normalized to be 1.
- Red curve: Average of energy consumption per energy estimate value in 80°C.
- Green curve: Average of energy consumption per energy estimate value in 55°C.
- Orange curve: Average of energy consumption per energy estimate value in 25°C.
- Blue curve: Average of energy consumption per energy estimate value in –10°C.

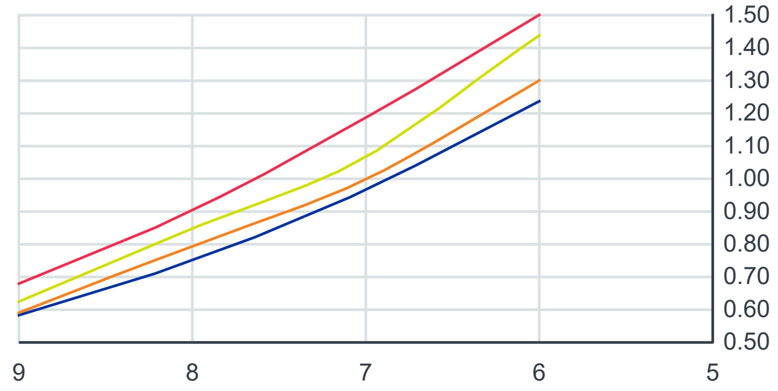

Figure 3: Temperature's impact on energy consumption and energy estimate value

The graph shows that energy consumption increases when the temperature increases. The amount of increase compared to the nominal temperature of 25°C can be seen on the y-axis. If energy estimate value 7 is returned in 25°C, the normalized energy consumption level is 1. In 85°C, the energy consumption level is approximately 1.18. This means that if the temperature changes from 25°C to 85°C with the energy estimate value 7, energy consumption is expected to increase in this example by 18 %.

In a modem, the lowest energy consumption is gained in low temperatures, which is shown by the –10°C curve in Figure 3: Temperature's impact on energy consumption and energy estimate value on page 7. An application can use the temperature information to plan for energy efficient data transmission. For example, if the daytime temperature is significantly higher than the nighttime temperature, data transmission can be centered around the nighttime. However, there can be other reasons for an application to avoid transmitting in very low temperatures, such as reduced battery capacity in lower temperatures.

If an application needs to consider temperature when checking the conditions for an energy efficient transmission, temperature notifications can be subscribed with the Nordic-proprietary **`%XTEMP`** *AT command*.

3 Connection-related features

nRF91 Series devices support other additional connection-related features that can be used to optimize current consumption.

The application can measure the duration of a connection in a data transmission with the **+CSCON** *AT command*.

The amount of energy consumed in a data transmission can vary between operators. By default, the network waits for a certain inactivity time for the device to continue data transmission after the last data has been transmitted to ensure that the connection is not released too early, as shown in the following figure.

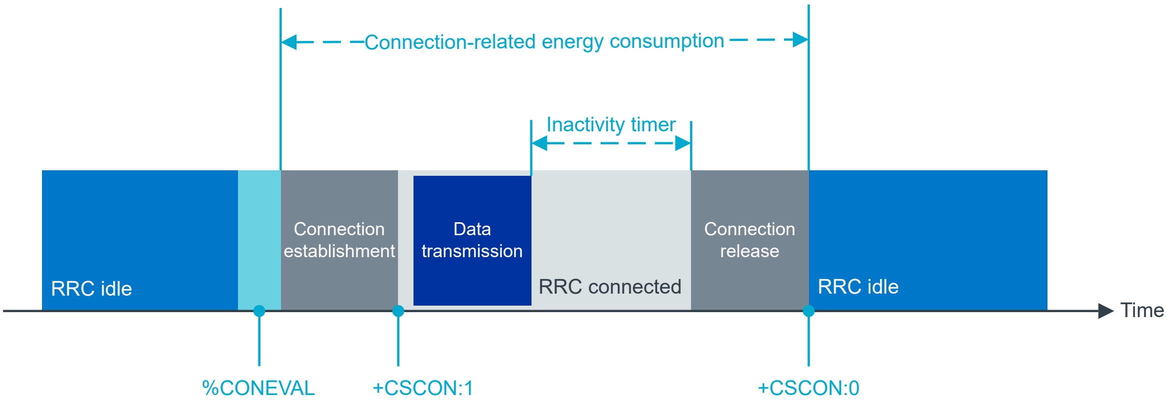

Figure 4: Data transmission and duration of RRC connection

With the **%RAI** AT command, a device can indicate to the network that there is no more data to be transmitted. This can help release the connection faster and minimize the duration of the RRC connected mode. Support for the *RAI* feature is network-specific.

For more information on the **+CSCON** and **%RAI** AT commands, see nRF9160 AT Commands or nRF91x1 Cellular AT Commands.

4 Appendix

Energy consumption measurements can be performed in a live network, for example, by using a test setup where Nordic Semiconductor's Power Profiler Kit II is connected to a nRF91 Series DK.

This hardware setup is shown in the following image.

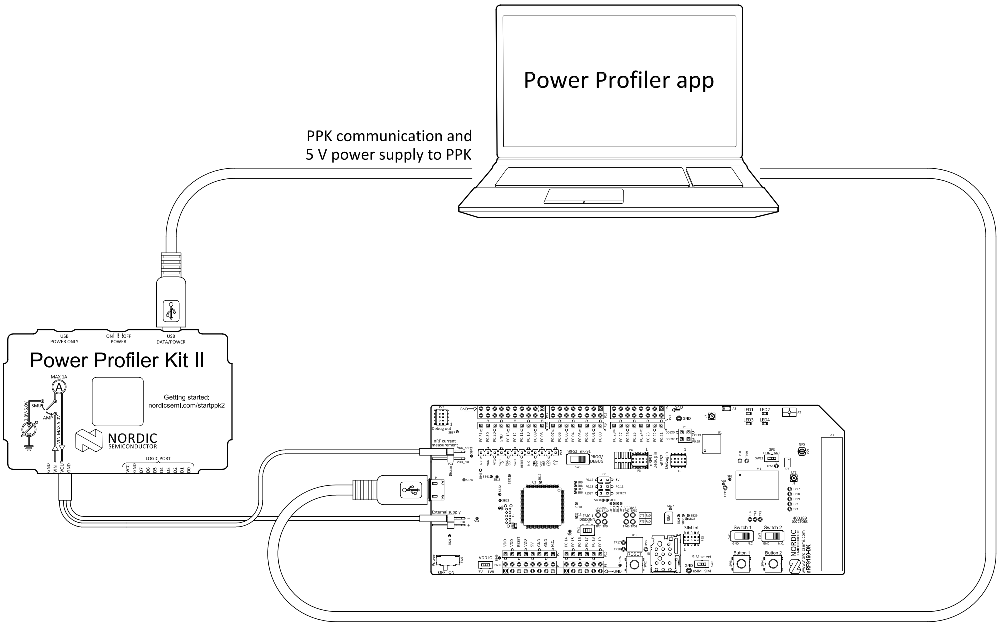

Figure 5: Hardware setup for measuring energy consumption

For details on the connections and pins, see Power Profiler Kit II.

Glossary

AT command

A command used to control the modem.

Cat-NB1

NB-IoT *User Equipment (UE)* category with 200 kHz UE bandwidth and a single RX antenna, specified in 3GPP Release 13.

Cat-NB2

An upgraded version of *Cat-NB1*, specified in 3GPP Release 14.

Discontinuous Reception (DRX)

A method in mobile communication to conserve the battery of a mobile device by turning the RF modem in a sleep state.

Internet of Things (IoT)

Physical objects that are embedded with sensors, processing ability, software, and other technologies that connect and exchange data with other devices and systems of the Internet or other communications networks.

Long-Term Evolution (LTE)

A wireless broadband communication standard for mobile devices and data terminals, based on the GSM/EDGE and UMTS/HSPA technologies.

LTE-M

An open standard that is most suitable for medium throughput applications requiring low power, low latency, and/or mobility, like asset tracking, wearables, medical, POS, and home security applications. Also known as Cat-M1.

Narrowband Internet of Things (NB-IoT)

A narrowband technology standard with longer range, lower throughput, and better penetration in, for example, cellars and parking garages compared to LTE-M. NB-IoT is most suitable for static, low throughput applications like smart metering, smart agriculture, and smart city applications. Also known as *Cat-NB1* or *Cat-NB2*.

Release Assistance Indication (RAI)

A 3GPP feature that allows an *LTE-M* or *Narrowband Internet of Things (NB-IoT)* device to indicate to the eNB that it has no more UL data and that the device does not anticipate receiving further DL data.

Reference Signal Received Power (RSRP)

The average power level received from a single reference signal in an LTE (Long-Term Evolution) network.

Signal-to-Noise Ratio (SNR)

The level of signal power compared to the level of noise power, often expressed in decibels (dB).

User Equipment (UE)

Any device used by an end-user to communicate. The UE consists of the Mobile Equipment (ME) and the Universal Integrated Circuit Card (UICC).

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