nRF9160 Modem Sleep Notifications

nWP-041

White Paper

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NORDIC® SEMICONDUCTOR

Contents

Revision history

Date	Description
2021-07-06	First release

1 Introduction

This document describes the use of the **%XMODEMSLEEP** and **%XT3412** *AT command*s.

Modem sleep notifications are sent by the **%XMODEMSLEEP** *AT command*. They are used to track the nRF9160 modem's inactivity and to receive prewarnings of its predicted activity. During the modem's inactivity, certain hardware components can be deactivated, and hardware resources, such as the antenna or battery, can be used for other purposes. Before the predicted end of sleep or before requesting an operation that requires the use of the modem’s radio resources, the application must activate the components that are needed for LTE connections if they have been switched off to save power during modem inactivity.

Timer T3412 notifications are sent by the **%XT3412** *AT command*. They are used to determine when the modem is expected to transmit. During a timer T3412 period, if the modem is not in *Power Saving Mode (PSM)*, it only monitors pagings and performs cell reselection. A received paging, change of the serving cell, or uplink signaling can interrupt a T3412 period.

The general syntaxes and parameters of the **%XMODEMSLEEP** and **%XT3412** *AT command*s are described in nRF91 AT Commands Reference Guide.

2 Subscribing notifications

Modem sleep notifications can be subscribed and unsubscribed with the **%XMODEMSLEEP** *AT command*. T3412 notifications can be subscribed and unsubscribed with the **%XT3412** *AT command*. The prewarning period and threshold for the shortest notified sleep or the timer T3412 period are specified when the notifications are subscribed.

Prewarning period 0 can be used if a prewarning is not wanted. In a long *PSM* sleep, the time value in the notifications can exceed the 32-bit integer value.

Syntax for subscribing modem sleep notifications:

```
%XMODEMSLEEP=1,<warning_time>,<threshold>
```

Syntax for subscribing timer T3412 notifications:

```
%XT3412=1,<warning_time>,<threshold>
```

Modem sleep notifications and timer T3412 notifications can be subscribed independently of each other.

3 Sleep types

The **%XMODEMSLEEP** *AT command* sends notifications of different types of modem sleep periods. The sleep types are *PSM*, RF inactivity, limited service, and flight mode.

3.1 PSM sleep

PSM sleep is typically a longer sleep that ranges from minutes to hours. The *PSM* period starts after radio connection has ended when the negotiated activity time has elapsed.

The network knows when the *User Equipment (UE)* is in *PSM*. During that period, the network does not try to contact the *UE*, and the *UE* does not monitor the serving cell. *PSM* ends when timer T3412 expires and the *UE* performs a periodic *Tracking Area Update (TAU)*. The application can interrupt *PSM* at any time with uplink data or other activity that triggers the establishing of a radio connection.

The application can synchronize uplink data with the *PSM* period by using modem sleep notifications. If uplink data is sent before the *PSM* sleep ends, there is no need to perform a periodic *TAU*, and the amount of signaling is reduced. The prewarning notification can be used as a trigger to send uplink data.

The application can save power by deactivating hardware components during *PSM* sleep and allocating resources used by the modem for other purposes.

The following notification example indicates the activation of *PSM* sleep with a 200000 ms period:

```
%XMODEMSLEEP: 1,200000
```

The following notification example is a prewarning of the end of the *PSM* sleep 1500 ms before the sleep ends:

```
%XMODEMSLEEP: 1,1500
```

The following notification example indicates that the *PSM* sleep has ended as <warning_time> is `0`:

```
%XMODEMSLEEP: 1,0
```

3.2 RF inactivity sleep

RF inactivity sleep is usually caused by *Extended Discontinuous Reception (eDRX)*. RF inactivity ranges typically from seconds to minutes. When an RF inactivity sleep ends, the modem continues to monitor the serving cell and can be reached by the network.

Synchronizing uplink data with RF inactivity sleep does not offer any power savings. The application can save power by deactivating hardware components during RF inactivity sleep and allocating resources used by the modem for other purposes.

The following notification example indicates the activation of RF inactivity sleep with a 20000 ms period:

```
%XMODEMSLEEP: 2,20000
```

The following notification example is a prewarning of the end of the RF inactivity sleep 1500 ms before the sleep ends:

```
%XMODEMSLEEP: 2,1500
```

The following notification example indicates that the RF inactivity sleep has ended as <warning_time> is 0:

```
%XMODEMSLEEP: 2,0
```

3.3 Limited service sleep

During limited service sleep, the modem sleeps between cell search attempts. The length of the sleep depends on the search pattern. The application configuration can affect which search pattern is used.

Synchronizing uplink data with limited service sleep does not offer any power savings. The *UE* is not camped on a cell where data sending is possible. The application can save power by deactivating hardware components during limited service sleep and allocating resources used by the modem for other purposes.

The following notification example indicates the activation of limited service sleep with a 20000 ms period:

```
%XMODEMSLEEP: 3,20000
```

The following notification example is a prewarning of the end of the limited service sleep 1500 ms before the sleep ends:

```
%XMODEMSLEEP: 3,1500
```

The following notification example indicates that the limited service sleep has ended as <warning_time> is 0:

```
%XMODEMSLEEP: 3,0
```

3.4 Flight mode sleep

During flight mode sleep, the modem sleeps because the application has deactivated it. The length of the sleep cannot not be determined, and a prewarning is not sent. The sleep ends when the application activates the modem.

The application can save power by deactivating hardware components during flight mode sleep and allocating resources used by the modem for other purposes.

The following notification example indicates the activation of flight mode sleep:

```
%XMODEMSLEEP: 4
```

The following notification example indicates that the flight mode sleep has ended:

```
%XMODEMSLEEP: 4,0
```

4 Sleep interruptions and resume

The **%XMODEMSLEEP** *AT command* sends notifications of the interruptions and ends of modem sleeps. A sleep can be interrupted by the application, *Global Navigation Satellite System (GNSS)*, or modem.

4.1 Sleep interrupted by application

Before interrupting sleep, for example, with uplink data, the application must activate hardware components and ensure that resources are available for the modem. After this, uplink data or any other request can be sent to the modem. After modem activity, sleep is not resumed, but a new sleep period starts instead.

The following notification example indicates that the modem sleeps:

```
%XMODEMSLEEP: <type>,120000
```

The following notification example indicates that the modem sleep has ended:

```
%XMODEMSLEEP: <type>,0
```

4.2 Sleep interrupted and resumed by GNSS

If the application has configured *GNSS* to track position, any sleep type might be interrupted by *GNSS* activity.

The application must react to a sleep interrupt notification immediately by activating hardware components and making resources available for the modem. A delay in reacting to the sleep interrupt notification impacts the modem's and *GNSS*'s performance. When sleep is resumed after *GNSS* activity, the remaining sleep time is notified.

A delay in the application’s reaction to a sleep interrupt notification is inevitable, and even a small delay affects the *GNSS* performance. Using *GNSS* and controlling resources according to sleeps must be considered case by case to determine if it offers power savings.

The following notification example indicates that the modem sleeps due to *eDRX*:

```
%XMODEMSLEEP: 2,120000
```

The following notification example indicates that *GNSS* activity interrupts the sleep:

```
%XMODEMSLEEP: 5,0
```

The following notification example indicates that the sleep is resumed after *GNSS* activity:

```
%XMODEMSLEEP: 6,70000
```

4.3 Sleep interrupted by modem

In some cases, the modem might end sleep before the predicted time, for example, due to *Universal Integrated Circuit Card (UICC)* activity. The application must react to the sleep end notification immediately by activating hardware components and making resources available for the modem.

A delay in reacting to the sleep interrupt notification impacts the modem's and *GNSS*'s performance. After modem activity, sleep is not resumed, but a new sleep period starts instead.

The following notification example indicates that the modem sleeps:

```
%XMODEMSLEEP: <type>,120000
```

The following notification example indicates that the modem sleep has ended:

```
%XMODEMSLEEP: <type>,0
```

5 Synchronizing data with timer T3412

If *PSM* sleep cannot be used, the application can synchronize uplink data with periodic *TAU* by using timer T3412 notifications the same way as *PSM* sleep notifications. A prewarning of timer T3412's expiration can be used to trigger uplink data.

Hardware components must not be deactivated based on timer T3412 notifications because the modem is active and using the resources.

The following notification example indicates that timer T3412 has started with a 3600000 ms value after connection release:

```
%XT3412: 3600000
```

The following notification example is a prewarning of timer T3412's expiration 5000 ms before the timer expires:

```
%XT3412: 5000
```

The following notification example indicates that timer T3412 has expired:

```
%XT3412: 0
```

6 Example sequences

The example sequences in this section describe the modem sleep periods during which the application and modem can save power and resources.

6.1 Synchronizing uplink data with PSM sleep

Uplink data can be synchronized with *PSM* sleep. The application can use *PSM* sleep as a trigger to send uplink data.

The following command example subscribes sleep notifications with a 2000 ms prewarning and a 60000 ms threshold:

```
AT%XMODEMSLEEP=1,2000,60000
OK
```

The following command example subscribes timer T3412 notifications with a 2000 ms prewarning and a 60000 ms threshold:

```
AT%XT3412=1,2000,60000
OK
```

The following command example activates the modem:

```
AT+CFUN=1
OK
```

The following notification example indicates that the modem is registered to the network. T3412 is negotiated with a 72-minute value and radio connection is released:

```
%XT3412: 4320000
```

The following notification example indicates a 10-second active time elapsing and the modem starting *PSM* sleep:

```
%XMODEMSLEEP: 1,4310000
```

The following notification example is a prewarning of the end of the *PSM* sleep:

```
%XT3412: 2000
%XMODEMSLEEP: 1,2000
```

The following notifications are sent when the application has interrupted *PSM* sleep with uplink data or the modem has ended *PSM* sleep:

```
%XT3412: 0
%XMODEMSLEEP: 1,0
```

6.2 Controlling hardware with sleep notifications

Any sleep type can be used to control hardware. The threshold for the sleep length must be set to notify only sleeps where controlling the hardware saves power or resources can be allocated for other use.

The following command example subscribes sleep notifications with a 1000 ms prewarning and a 60000 ms threshold:

```
AT%XMODEMSLEEP=1,1000,60000
OK
```

The following command example activates the modem:

```
AT+CFUN=1
OK
```

The following notification example indicates that the modem sleeps for 120 seconds:

```
%XMODEMSLEEP: <type>,120000
```

The following notification example is a prewarning of the end of the modem sleep 1000 ms before the sleep ends:

```
%XMODEMSLEEP: <type>,1000
```

The following notification example indicates that the modem sleep has ended:

```
%XMODEMSLEEP: <type>,0
```

6.3 GNSS activity during sleep

GNSS can interrupt and resume an ongoing sleep.

The following command example subscribes sleep notifications with a 5000 ms prewarning and a 60000 ms threshold:

```
AT%XMODEMSLEEP=1,5000,60000
OK
```

The following command example activates the modem:

```
AT+CFUN=1
OK
```

The following notification example indicates that the modem sleeps for 120 seconds due to *eDRX*:

```
%XMODEMSLEEP: 2,120000
```

The following notification example indicates that *GNSS* activity interrupts sleep:

```
%XMODEMSLEEP: 5,0
```

The following notification example indicates that sleep is resumed after *GNSS* activity and that the remaining sleep period is 70 seconds:

```
%XMODEMSLEEP: 6,70000
```

The following notification example indicates that *GNSS* activity interrupts sleep:

```
%XMODEMSLEEP: 5,0
```

The following notification example is a prewarning of the end of the sleep 5000 ms before the sleep ends:

```
%XMODEMSLEEP: 2,5000
```

The following notification example indicates that sleep is resumed and that the remaining sleep period is 2 seconds:

```
%XMODEMSLEEP: 6,2000
```

The following notification example indicates that the modem sleep has ended:

```
%XMODEMSLEEP: 2,0
```

Glossary

AT command

A command used to control the modem.

Extended Discontinuous Reception (eDRX)

A method to conserve the battery of an IoT (Internet of Things) device by allowing it to remain inactive for extended periods.

Global Navigation Satellite System (GNSS)

A satellite navigation system with global coverage. The system provides signals from space transmitting positioning and timing data to GNSS receivers, which use this data to determine location.

Power Saving Mode (PSM)

A feature introduced in 3GPP Release 12 to improve battery life of IoT (Internet of Things) devices by minimizing energy consumption. The device stays dormant during the PSM window.

Subscriber Identity Module (SIM)

A card used in *UE* containing data for subscriber identification.

System in Package (SiP)

A number of integrated circuits, often from different technologies, enclosed in a single module that performs as a system or subsystem.

Tracking Area Update (TAU)

A procedure initiated by the *UE* when moving to a new tracking area in the LTE (Long-term Evolution) system.

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).

Universal Integrated Circuit Card (UICC)

A new generation *Subscriber Identity Module (SIM)* used in *UE* for ensuring the integrity and security of personal data.

Acronyms and abbreviations

These acronyms and abbreviations are used in this document.

eDRX
: Extended Discontinuous Reception

GNSS
: Global Navigation Satellite System

PSM
: Power Saving Mode

SIM
: Subscriber Identity Module

SiP
: System in Package

TAU
: Tracking Area Update

UE
: User Equipment

UICC
: Universal Integrated Circuit Card

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