JN51xx Core Utilities User Guide

JN-UG-3116
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Contents

Part II: Reference Information

Preface

This manual provides a single point of reference for information relating to the JN51xx Core Utilities (JCU), for use with the NXP JN51xx family of wireless microcontrollers. The manual provides both conceptual and practical information concerning the JCU, and provides guidance on use of the JCU Application Programming Interfaces (APIs). The API resources (functions and structures) are fully detailed.

The JN51xx Core Utilities are designed to be used when developing applications for the JN51xx devices, such as ZigBee PRO wireless network applications. This manual should be used throughout JN51xx application development.

Organisation

This manual is divided into two parts:

- Part I: Concept and Operational Information comprises five chapters:
  - Chapter 1 introduces the JN51xx Core Utilities and associated APIs
  - Chapter 2 describes how to use the Persistent Data Manager (PDM) for EEPROM
  - Chapter 3 describes how to use the Power Manager (PWRM)
  - Chapter 4 describes how to use the Protocol Data Unit Manager (PDUM)
  - Chapter 5 describes how to use the Debug (DBG) module
- Part II: Reference Information comprises five chapters:
  - Chapter 6 describes the functions of the PDM API for EEPROM
  - Chapter 7 describes the functions of the PWRM API
  - Chapter 8 describes the functions of the PDUM API
  - Chapter 9 describes the functions of the DBG API
  - Chapter 10 details the structures used by the JCU

Conventions

Files, folders, functions and parameter types are represented in **bold** type.

Function parameters are represented in *italics* type.

Code fragments are represented in the `Courier New` typeface.

This is a **Tip**. It indicates useful or practical information.

This is a **Note**. It highlights important additional information.

*This is a **Caution**. It warns of situations that may result in equipment malfunction or damage.*

Acronyms and Abbreviations

APDU	Application Protocol Data Unit
API	Application Programming Interface
DBG	Debug
EEPROM	Electrically Erasable Programmable Read-Only Memory
MAC	Media Access Control
PAN	Personal Area Network
NPDU	Network Protocol Data Unit
NVM	Non-Volatile Memory
PDU	Protocol Data Unit
PDUM	Protocol Data Unit Manager
PDM	Persistent Data Manager
PIC	Programmable Interrupt Controller
PWRM	Power Manager
SDK	Software Developer's Kit

UART	Universal Asynchronous Receiver-Transmitter
ZPS	ZigBee PRO Stack

Related Documents

JN-UG-3087	JN516x Integrated Peripherals API User Guide
JN-UG-3118	JN517x Integrated Peripherals API User Guide
JN-UG-3113	ZigBee 3.0 Stack User Guide
JN-DS-JN516x	JN516x Data Sheet (for JN5168, JN5164 and JN5161)
JN5169	JN5169 Data Sheet
JN517X	JN517x Data Sheet

Support Resources

To access online support resources such as SDKs, Application Notes and User Guides, visit the Wireless Connectivity area of the NXP web site:

www.nxp.com/products/interface-and-connectivity/wireless-connectivity

All NXP resources referred to in this manual can be found at the above address, unless otherwise stated.

Trademarks

Chip Compatibility

The software described in this manual can currently be used on the NXP JN516x and JN517x families of wireless microcontrollers. However, for future compatibility, the compatible microcontrollers are referred to as JN51xx devices in this manual.

Part I:
Concept and Operational Information

1. Introduction

The JN51xx Core Utilities (JCU) are designed for use in wireless network applications for the NXP JN51xx devices, providing an interface which simplifies the programming of a range of operations that are not specific to wireless networking.

1.1 Modules and Architecture

The JN51xx Core Utilities comprise four utilities/modules, each with a dedicated Application Programming Interface (API) to facilitate easy interaction between the application and the corresponding JCU module. Each module's API consists of a set of C functions and associated resources.

1.1.1 JCU Modules

The JCU modules are briefly described below:

- **Persistent Data Manager (PDM):** This module handles the storage of context and application data in Non-Volatile Memory (NVM), and the retrieval of this data. It provides a mechanism by which the JN51xx device can resume operation without loss of continuity following a power loss. For the JN516x and JN517x devices, this NVM is internal EEPROM. The PDM module is described in Chapter 2.
- **Power Manager (PWRM):** This module manages the transitions of the JN51xx device into and out of low-power modes, such as sleep mode. The PWRM module is described in Chapter 3.
- **Protocol Data Unit Manager (PDUM):** This module is concerned with managing memory, as well as inserting data into messages to be transmitted and extracting data from messages that have been received. The PDUM module is described in Chapter 4.
- **Debug (DBG):** This module allows diagnostic messages to be output when the application runs, as an aid to debugging the application code. The DBG module is described in Chapter 5.

Note 1: The JCU modules are supplied in the NXP Software Developer's Kit (SDK) for the wireless networking protocols. Not all of the JCU modules are provided in every SDK - for details of the supplied modules, refer to the Release Notes of your SDK.

Note 2: Not all of the supplied JCU modules need to be used in the JN51xx application. The modules can be individually enabled for use by the application - for details, refer to the chapters for the modules.

1.1.2 Software Architecture

On a JN51xx-based node in a wireless network, the JCU interacts with the following software blocks:

- User application (through use of the JCU APIs in the application code)
- Wireless networking stack (e.g. ZigBee PRO stack)
- JN51xx integrated peripherals

The JCU can be envisaged as sitting alongside the wireless networking stack and the JN51xx Integrated Peripherals API, as depicted in the diagram below.

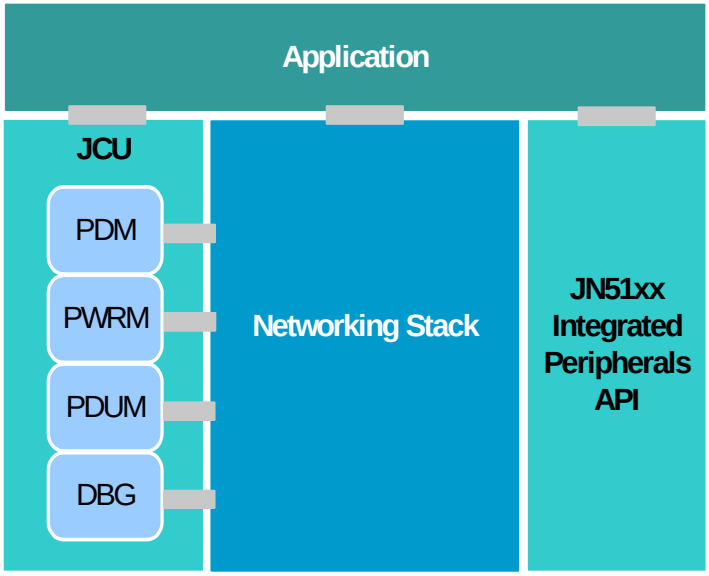

Figure 1: Basic Software Architecture

2. Persistent Data Manager (PDM)

This chapter describes the Persistent Data Manager (PDM) module which handles the storage of stack context data and application data in Non-Volatile Memory (NVM). For the JN516x and JN517x devices, this memory is internal EEPROM and this chapter will therefore refer to EEPROM.

Note : The PDM functions referenced in this chapter are detailed in Chapter 6.

Tip: In this chapter, a cold start refers to either a first-time start or a re-start without memory (RAM) held. A warm start refers to a re-start with memory held (for example following sleep with memory held).

2.1 Overview

If the data needed for the operation of a network node is stored only in on-chip RAM, this data is maintained in memory only while the node is powered and will be lost during an interruption to the power supply (e.g. power failure or battery replacement). This data includes context data for the network stack and application data.

In order for the node to recover from a power interruption with continuity of service, provision must be made for storing essential operational data in Non-Volatile Memory (NVM), such as EEPROM. This data can then be recovered during a re-boot following power loss, allowing the node to resume its role in the network.

The storage and recovery of operational data in JN516x/7x EEPROM can be handled using the Persistent Data Manager (PDM) module, as described in the rest of this chapter, which covers the following topics:

- Initialising the PDM module - see Section 2.2
- Managing data in EEPROM - see Section 2.3
- Storing counters in EEPROM - see Section 2.4
- PDM features including mutexes, EEPROM wear counts and event handling - see Section 2.5

The PDM can be used with ZigBee PRO, JenNet-IP and IEEE802.15.4 wireless networking protocols.

2.2 Initialising the PDM and Building a File System

The PDM module must be initialised by the application following a cold or warm start, irrespective of the PDM functionality used (e.g. context data storage or counter implementation). PDM initialisation is performed using the function **PDM_eInitialise()**.

This function requires the following information to be specified:

- The number of EEPROM segments to be used by PDM (a zero value means use all segments)
- An optional mutex in order to serialise PDM function calls and prevent concurrent calls - for information on this mutex, refer to Section 2.5

Once the **PDM_eInitialise()** function has been called, the PDM module builds a file system in RAM containing information about the segments that it manages in EEPROM. The PDM reads the header data from each EEPROM segment and builds the file system.

The file system allows the PDM to perform efficient searches when operating on data, track the occupation of all the segments in the EEPROM and keep track of the number of segments available for data allocation at any time. It also helps to even out the wear across EEPROM segments - for more information on EEPROM segment wear, refer to Section 2.5.4.

For ZigBee PRO, the PDM is used in its most general form, as described above, in which the serialisation mutex is optional. The sub-sections below provide special instructions for using the PDM with the IEEE802.15.4 and JenNet-IP protocols.

2.2.1 Using PDM with IEEE802.15.4

To use the PDM in applications developed using a ZigBee 3.0 SDK (JN-SW-4170 or JN-SW-4270) or the IEEE802.15.4 SDK (JN-SW-4163), the flag PDM_NO_RTOS must be defined in the makefile, as follows:

```
CFLAGS += -DPDM_NO_RTOS
```

The serialisation mutex cannot be used in this case and the relevant parameter is removed from the **PDM_eInitialise()** function.

2.2.2 Using PDM with JenNet-IP

When the PDM is used in applications developed using the JenNet-IP SDK (JN-SW-4165), no makefile modifications need to be made. However, the serialisation mutex is always implemented and a non-zero value must be passed to the relevant parameter in the **PDM_eInitialise()** function.

2.3 Managing Data in EEPROM

This section describes use of the PDM module to persist data in EEPROM in order to provide continuity of service when the JN51xx device resumes operation after a cold start or a warm start without memory held.

Data is stored in EEPROM in terms of 'records'. A record occupies at least one EEPROM segment but may be larger than a segment and occupy multiple segments. Any number of records of different lengths can be created, provided that they do not exceed the EEPROM capacity. The records are created automatically for stack context data and by the application (as indicated in Section 2.3.1) for application data. Each record is identified by a unique 16-bit value which is assigned when the record is created - for application data, this identifier is user-defined.

The stack context data which is stored in EEPROM includes the following:

- Application layer data:
  - AIB members, such as the EPID and ZDO state
  - Group Address table
  - Binding table
  - Application key-pair descriptor
  - Trust Centre device table
- Network layer data:
  - NIB members, such as PAN ID and radio channel
  - Neighbour table
  - Network keys
  - Address Map table

On performing a JN51xx cold start or warm start without RAM held, the PDM must be initialised in the application as described in Section 2.2.

- If this is the first ever cold start, there will be no stack context data or application data preserved in the EEPROM.
- If it is a cold or warm start following previous use (such as after a reset), there should be stack context data and application data preserved in the EEPROM.

On start-up, the PDM builds a file system in RAM and scans the EEPROM for valid data. If any data is found, it is incorporated in the file system.

The PDM saves a Cyclic Redundancy Code (CRC) for each segment of a record. Any failure will result in the data being unrecoverable and the record becoming invalid.

Saving, recovering and deleting application data in EEPROM are described in the sub-sections below.

2.3.1 Saving Data to EEPROM

Application data and stack context data are saved from RAM to EEPROM as described below.

Note: During a data save, if the EEPROM needs to be defragmented and purged, this will be performed automatically resulting in all records being re-saved.

Application Data

You should save application data to EEPROM when important changes have been made to the data in RAM. Application data in RAM can be saved to an individual record in EEPROM using the function **PDM_eSaveRecordData()**. A buffer of data in RAM is saved to a single record in EEPROM (a record may span multiple EEPROM segments).

The first time that a record is saved using **PDM_eSaveRecordData()**, the record is created and the data is written in its entirety, provided there are enough free EEPROM segments to hold the data (you can first find out how many segments are available using the function **PDM_u8GetSegmentCapacity()**). When a record is first created, a unique 16-bit identifier must be assigned to the record by the application - this identifier is subsequently used to reference the record. The value used must not clash with those used by the NXP libraries - the ZigBee PRO stack libraries use values above 0x8000 and the JenNet-IP libraries use values between 0x3000 and 0x3007.

Subsequently, in performing a re-save to the same record (specified by its 16-bit identifier), the original EEPROM segments associated with the record will be over-written but only the segment(s) containing data changes will be altered (if no data has changed, no write will be performed). This method of only making incremental saves improves the occupancy level of the size-restricted EEPROM.

If a save fails, the function **PDM_eSaveRecordData()** will return the code PDM_E_STATUS_NOT_SAVED. Alternatively, the callback event E_PDM_SYSTEM_EVENT_DESCRIPTOR_SAVE_FAILED can be used to notify the application of a save failure - this requires a PDM callback function to have been registered using the function **PDM_vRegisterSystemCallback()**, as described in Section 2.5.2.

Stack Context Data

The NXP ZigBee PRO stack automatically saves its own context data from RAM to EEPROM when certain data items change. This data will not be encrypted.

2.3.2 Recovering Data from EEPROM

Application data and stack context data are loaded from the EEPROM to RAM as described below.

Application Data

Application data records in EEPROM can be read by the application using the function **PDM_eReadDataFromRecord()**. The record to be read is specified using its 16-bit identifier and a data buffer in RAM must also be specified in which the read data will be stored.

Before calling **PDM_eReadDataFromRecord()**, it may be useful to call the function **PDM_bDoesDataExist()** in order to determine whether a record with the specified identifier exists in the EEPROM and, if it does, to obtain its size and therefore the length of the required RAM buffer.

During a cold start or a warm start without memory held, once the PDM module has been initialised (see Section 2.2), **PDM_eReadDataFromRecord()** must be called for each record of application data in EEPROM that needs to be copied to RAM.

Stack Context Data

The function **PDM_eReadDataFromRecord()**, described above, is not used for records of stack context data. Loading this data from the EEPROM to RAM is handled automatically by the stack (provided that the PDM has been initialised).

2.3.3 Deleting Data in EEPROM

An individual record of application data in the EEPROM can be deleted using the function **PDM_eDeleteData()** - the record to be deleted is specified using its 16-bit identifier. Alternatively, all records (application data and stack context data) in the EEPROM can be deleted using the function **PDM_eDeleteAllData()**.

Caution: *You are not recommended to delete records of ZigBee PRO stack context data by calling* ***PDM_eDeleteAllData()*** *before a rejoin of the same secured network. If these records are deleted, data sent by the node after the rejoin will be rejected by the destination node since the frame counter has been reset on the source node. For more information and advice, refer to the "Application Design Notes" appendix in the ZigBee 3.0 Stack User Guide (JN-UG-3113).*

2.4 Storing Counters in EEPROM

The PDM provides a means of using the JN516x/7x EEPROM to store counters, such as frame counters and acknowledgement sequences, as found in many communications protocols. A counter is implemented within a single EEPROM segment as follows:

- **Start value** which is held in pure binary form inside the counter's header
- **Incremental value** (over the start value) which is represented as a bitmap

Each bit of the bitmap represents an increment (by one) of the counter and is set when the corresponding increment occurs. There is a maximum incremental value that can be represented in one segment. When this value is reached, the counter is silently moved to a new segment in which the start value (in the header) is increased appropriately and the bitmap is reset to zero. To avoid increasing the segment wear count, the old bitmap segment is not formally deleted when a new segment is started. This process continues while there are segments free in the EEPROM.

The sub-sections below describe how to manage a counter in EEPROM using the PDM functions.

2.4.1 Creating a Counter

The function **PDM_eCreateBitmap()** can be used to create a counter in the EEPROM. In this function call, the new counter must be given a user-defined 16-bit identifier and a start value (these values will be stored in the counter's header).

2.4.2 Incrementing a Counter

The application can increment the counter by calling the function **PDM_eIncrementBitmap()**. When an increment results in the counter filling the current bitmap/segment, the function will indicate this by returning PDM_E_STATUS_SATURATED_OK. The next time the function is called, the counter will automatically be moved to a new bitmap/segment (as described above). However, if there is no free segment available, the function will be unable to perform the increment and will return PDM_E_STATUS_USER_PDM_FULL.

2.4.3 Reading a Counter

A counter in EEPROM can be read using the function **PDM_eGetBitmap()**. This function obtains the start value (stored in the counter's header) and the incremental value from the bitmap. The current value of the counter is then the sum of these two results.

The above function should be called when the JN516x/7x device comes up from a cold start, to check whether a counter is present in EEPROM.

2.4.4 Deleting a Counter

Once a counter is no longer required, it can be removed from EEPROM using the function **PDM_eDeleteBitmap()**. This clears the current segment and all the older (expired) segments for the counter. This deleton increments the wear counts for these segments (see Section 2.5.4) and should be done only if absolutely necessary, as expired bitmap segments can be re-used directly via the PDM without formal deletion.

2.5 PDM Features

2.5.1 Mutex in PDM

PDM functions are not re-entrant and a mutex can be optionally used to prevent concurrent PDM function calls - if enabled, the mutex is applied automatically during a PDM function call. If required, a mutex can be specified when the PDM module is initialised using the function **PDM_eInitialise()** - see Section 2.2.

Note: The mutex does not remain optional when the PDM is used with IEEE802.15.4, ZigBee 3.0 and JenNet-IP applications. In applications developed using a ZigBee 3.0 SDK (JN-SW-4170 or JN-SW-4270) or the IEEE802.15.4 SDK (JN-SW-4163), the mutex is not available and the relevant parameter is removed from **PDM_eInitialise()**. In applications developed using the JenNet-IP SDK (JN-SW-4165), the mutex is always implemented and a non-zero value must be passed to the relevant parameter of **PDM_eInitialise()**. For more information, refer to Section 2.2.

2.5.2 Event and Error Handler for EEPROM

The internal PDM library allows a handler to be called to alert the application of events and error conditions in the JN516x/7x internal EEPROM. This callback function is registered by calling the function **PDM_vRegisterSystemCallback()**. The PDM events/error conditions are listed and described in Section 10.1.3.

An application must trap E_PDM_SYSTEM_EVENT_PDM_NOT_ENOUGH_SPACE and E_PDM_SYSTEM_EVENT_DESCRIPTOR_SAVE_FAILED callback errors during testing. The ZigBee PRO stack uses multiple records. Once an ‘out of space’ error has occurred, the records will be in an inconsistent state. The software must be altered to use smaller record sizes or an external SPI Flash device. The PDM record sizes for the ZigBee PRO stack are dependent on table sizes set in the ZPS Configuration Editor.

The registered callback function may also be designed to handle a Wear Count event E_PDM_SYSTEM_EVENT_WEAR_COUNT_TRIGGER_VALUE_REACHED which indicates that the Wear Count for an EEPROM segment has reached the configured trigger level (see Section 2.5.4).

2.5.3 EEPROM Capacity

The JN516x/7x internal EEPROM consists of multiple small segments. There are 63 segments of 64 bytes each. The internal PDM library can store no more than one data record in each segment, although a large record may be stored across multiple segments. The PDM library needs to store some system information in each segment, so in practice each segment can hold only up to 56 bytes of record data. This means that a PDM record that has a single byte of information will need the same space as a 56-byte record and that a 57-byte record will need two segments (the same as a 112-byte record).

The function **PDM_u8GetSegmentCapacity()** returns the number of segments that are free for PDM. The function **PDM_u8GetSegmentOccupancy()** returns the number of segments that are in use. One of these functions may be called after all the records have been created and saved (including records in the ZigBee PRO stack). When updating a record, the PDM saves the new data before deleting the old data (to ensure that data is retained over any unexpected power cycles). Therefore, there must be sufficient capacity in the EEPROM to store another copy of a record before the old copy is deleted. To allow for the worst-case scenario, the value returned by **PDM_u8GetSegmentCapacity()** must be greater than the number of segments required to store the largest record.

2.5.4 EEPROM Wear Count

An EEPROM device supports a limited number of data writes to each byte before the storage medium begins to fail. For the JN516x/7x EEPROM, at least 100000 writes are guaranteed and a million writes should be typically possible. For each EEPROM segment, a record is kept of the number of writes made to the segment so far. This is the ‘Wear Count’, which is stored and maintained in the segment header. The PDM manages the use of EEPROM segments in a way that minimises wear and attempts to spread the wear evenly across the segments.

The function **PDM_eGetSegmentWearCount()** allows the current value of the Wear Count of a particular segment to be obtained. It is also possible to set up the generation of an event when the Wear Count of any segment reaches a certain trigger level. This trigger level can be configured (for all segments) using the function **PDM_vSetWearCountTriggerLevel()**. The Wear Count event is E_PDM_SYSTEM_EVENT_WEAR_COUNT_TRIGGER_VALUE_REACHED and the user-defined PDM callback function (see Section 2.5.2) should be designed to process this Wear Count event.

2.5.5 Ensuring Consistency of PDM Records

The data in the PDM may differ in structure from that expected by the application. The structures stored by the ZigBee PRO libraries can change due to altering table sizes in the ZPS Configuration Editor, as well as between releases of the ZigBee PRO stack libraries. Inconsistency can occur under the following circumstances:

- The internal EEPROM on a JN516x/7x device is not erased when programming an application with the JN51xx Flash Programmer. If multiple applications are run on the same hardware, it is unlikely that the structures will be consistent between the applications.
- When a ZigBee Over-The-Air (OTA) software update is performed, the PDM data is not erased. This is normally a benefit because it allows the application to rejoin the network. However, if any of the PDM structures change, a factory reset must be performed by calling **PDM_eDeleteAllData()**

Applications normally contain a way to perform a factory reset of the PDM module - for example, by calling **PDM_eDeleteAllData()** if a button is held down during reset.

The application can automatically check for PDM consistency by storing an application-specific 'magic number' in a record. A new magic number should be used if the application software or ZigBee PRO libraries PDM usage is inconsistent with the previous version of the software. Immediately after calling **PDM_eInitialise()**, the application should call **PDM_eReadDataFromRecord()**. If the magic number does not match, the application should call **PDM_eDeleteAllData()** to erase all records before attempting to start the ZigBee PRO stack. If the call to **PDM_eReadDataFromRecord()** indicates that the record has not been found, the application should also call **PDM_eDeleteAllData()** because another application may have been running that does not use the same record ID but has written inconsistent ZigBee PRO records to the PDM module.

3. Power Manager (PWRM)

This chapter describes the Power Manager (PWRM) module, which manages the transitions of the JN51xx device into and out of low-power modes.

Low-power modes are typically used to prolong the battery life of a node by reducing the power consumption of the device during periods when the node does not need to receive, transmit or perform any other activities. Thus, low-power modes only apply to End Devices, as the Co-ordinator and Routers always need to remain fully alert for routing purposes.

3.1 Low-Power Modes

A number of low-power modes are available on the JN51xx device. In descending order of power consumption, the modes are:

- Doze mode
- Sleep modes:
  - Sleep with memory held
  - Sleep without memory held
- Deep Sleep mode

When the node is inactive, the Power Manager will put the device into the lowest power mode possible.

The above low-power modes are described in the sub-sections below. For further information on the low-power modes of a JN516x or JN517x device, refer to the relevant device Data Sheet.

3.1.1 Doze Mode

In Doze mode, the CPU of the chip pauses (the CPU clock is stopped) but all other parts of the JN51xx device continue to run. Any interrupt will cause Doze mode to terminate and the application program will continue running from the next instruction. To prevent the Watchdog firing when in Doze mode, the application should ensure that a timer is running at a higher frequency than the Watchdog expiry period.

3.1.2 Sleep Mode with Memory Held

During Sleep with memory held, the contents of on-chip RAM are maintained, including stack context data and application data. Thus, on waking, the device can recover from sleep very quickly to continue normal operation from the next instruction.

In this mode, all power domains are powered down except those for the on-chip RAM and VDD supply. In addition, the 32-kHz on-chip oscillator can optionally be left running, which allows the device to be woken from sleep using wake timers.

Otherwise, the device can only be woken by changes on the DIO pins or the comparator input, or by a pulse counter expiry.

Although the contents of memory are held, on waking it is still necessary to re-configure the IEEE 802.15.4 stack layers and to re-initialise most of the on-chip peripherals. Wake callback functions can be registered for this purpose:

- You DO NOT have to re-initialise the DIOs, wake timers and comparator.
- You DO have to re-initialise everything else, including all other on-chip peripherals, the IEEE 802.15.4 MAC layer and, if using callbacks, the Programmable Interrupt Controller (PIC) - the callback functions must be re-registered. On the JN51xx device, the SPI hardware must also be re-initialised.

3.1.3 Sleep Mode without Memory Held

During Sleep without memory held, on-chip RAM is powered down, and therefore stack context data and application data are not preserved on-chip. Normally, this data must be saved to NVM (Non-Volatile Memory) before the chip enters sleep mode, and then recovered from NVM on waking (see Chapter 2).

In this mode, all power domains are powered down except the VDD power supply domain. Again, the 32-kHz on-chip oscillator can optionally be left running, which allows the device to be woken from sleep using wake timers. Otherwise, the device can only be woken by changes on the DIO pins or the comparator input, or by a pulse counter expiry.

On waking, the application program must be re-loaded from Flash memory before the node can resume operation. All variables and peripherals must be re-initialised, except those used as wake sources and the DIO lines.

3.1.4 Deep Sleep Mode

In Deep Sleep mode, all switchable power domains are powered down and the 32-kHz oscillator is stopped. The device can be woken from deep sleep either via a hardware reset (by taking the RESETN pin low or by power cycling the device) or a change on the DIO pins.

On waking, the application program must be re-loaded from Flash memory before the node can resume operation. All variables and peripherals must be re-initialised, including the DIO lines.

3.2 Callback Functions for Power Manager

If you intend to use the Power Manager, a number of callback functions must be available for the Power Manager to call in order to:

- start the application (see Section 3.2.1)
- perform housekeeping tasks when entering and leaving low-power mode (see Section 3.2.2)
- handle interrupts from Wake Timer 1 (see Section 3.2.3)

3.2.1 Essential Callback Function

When your application uses the Power Manager, you must define and use the callback function **vAppMain()** in your code. The main task of your application must be included in this function (which must never return).

3.2.2 Pre-sleep and Post-sleep Callback Functions

In order to implement low-power modes, you must provide the Power Manager with user-defined callback functions to perform housekeeping tasks when the node enters and leaves low-power mode. Registration functions are provided for these callback functions, where the registration functions must be called in the user-defined callback function **vAppRegisterPWRMCallbacks()**.

- The pre-sleep callback function is called by the Power Manager just before putting the device into low-power mode. This callback function is registered in your code through the API function **PWRM_vRegisterPreSleepCallback()**.
- The post-sleep callback function is called by the Power Manager just after the device leaves low-power mode (irrespective of how the device was woken from sleep). This callback function is registered in your code through the API function **PWRM_vRegisterWakeupCallback()**.

vAppRegisterPWRMCallbacks() is called by the stack as part of a cold start.

The pre- and post-sleep callback function themselves must each be declared in the code using the macro

PWRM_CALLBACK(*fn_name***)**

where *fn_name* is the name of the callback function.

Each of these callback functions must also have a descriptor. This is a structure that is used in the above registering functions to specify the callback function to register.

The callback descriptor must be declared using the macro

PWRM_DECLARE_CALLBACK_DESCRIPTOR(*desc_name***,** *fn_name***)**

where *desc_name* is the descriptor name and *fn_name* is the callback function name.

For example:

```
PWRM_CALLBACK(vPreSleepCB1);
PWRM_DECLARE_CALLBACK_DESCRIPTOR(pscb1_desc, vPreSleepCB1);
```

3.2.3 Wake Timer Callback Function

If you intend to use wake events, derived from Wake Timer 1, your interrupt handler must call the pre-defined callback function **PWRM_WakeInterruptCallback()**. This function maintains the list of scheduled wake events - if required, it will re-start the wake timer for the next wake point. It also calls the user-defined callback function specified through **PWRM_vScheduleActivity()**.

For further information on waking the device using scheduled wake events, refer to Section 3.6.

3.3 Initialising and Starting the Power Manager

The Power Manager is initialised and started using the function **PWRM_vInit()**. This function requires one of five possible low-power configurations to be specified:

- Sleep with 32-kHz oscillator running and memory held
- Sleep with 32-kHz oscillator running and memory not held
- Sleep with 32-kHz oscillator not running and memory held
- Sleep with 32-kHz oscillator not running and memory not held
- Deep sleep (oscillator not running and memory not held)

The specified configuration is the low-power mode in which the Power Manager will attempt to put the device during inactive periods. Note that Doze mode cannot be explicitly specified, but the Power Manager may put the device into Doze mode at times when the specified mode cannot be entered (see Section 3.8.1).

The criteria for selecting a sleep mode are as follows:

- **Oscillator setting:**
  - If the 32-kHz oscillator is left running during sleep, a wake point can be scheduled using **PWRM_vScheduleActivity()** - see Section 3.6.
  - Otherwise, the device must be woken by an external event (a change on a DIO line or comparator input, a pulse counter expiry or a reset).
- **Memory setting:**
  - If memory is held during sleep, stack context data and application data will be preserved in memory, allowing the device to quickly resume operation through a warm re-start following sleep.
  - Sleep without memory held provides a greater power saving. However, stack context data and application data must be saved to NVM before entering sleep mode and restored into on-chip memory during a cold re-start on exiting sleep (see Chapter 2).

3.4 Enabling Power-Saving

To enable the Power Manager to put the JN51xx device into low-power mode at appropriate times, you must call the function **PWRM_vManagePower()**, normally from an idle loop. Once this function has been called, the Power Manager will, whenever possible, put the JN51xx device into the sleep mode specified through **PWRM_vInit()** (or, alternatively, into Doze mode - see Section 3.8.1).

Note: Sleep mode cannot be entered while there are software timers active (in running or expired states). You must therefore de-activate any such timers to allow the Power Manager to put the JN51xx device into sleep mode.

3.5 Non-interruptible Activities

In order to enter sleep mode, no activities must be running that must not be interrupted by sleep. This condition for entering sleep mode is monitored using an activity counter - sleep mode can only be entered when this counter is zero. The application is responsible for maintaining the activity counter, as follows:

- Whenever an activity is started that must not be interrupted by sleep, the application must notify the Power Manager using the function **PWRM_eStartActivity()**, which increments the activity counter.
- Whenever such an activity is completed, the application must notify the Power Manager using the function **PWRM_eFinishActivity()**, which decrements the activity counter.

***Caution: PWRM_eFinishActivity()** must only be called by an application following a matching call to **PWRM_eStartActivity()**. The ZigBee PRO stack also uses the activity counter, so calling **PWRM_eFinishActivity()** inappropriately can leave the ZigBee PRO stack in an inconsistent state.*

You can obtain the current value of the activity counter using the function **PWRM_u16GetActivityCount()**.

3.6 Terminating Low-Power Mode

Low-power modes can be terminated in a number of ways:

- **Any Interrupt:** When in Doze mode, the device can be woken by any interrupt.
- **Wake Timer:** When in Sleep mode in which the 32-kHz oscillator runs, the device can be woken by a scheduled wake event configured using the function **PWRM_vScheduleActivity()**. For more information on scheduled wake events, refer to Section 3.6.
- **External Wake Event:** The following external wake events are available:
  - **DIO:** When in Sleep and Deep Sleep modes, the device can be woken by a change of state of a DIO line.
  - **Comparator input:** When in Sleep mode, the device can be woken by a change of state of the comparator input.
  - **Pulse counter:** When in Sleep mode, the device can be woken on expiry of the pulse counter, which counts pulses on an external input.

  The above external wake events can be controlled by functions of the JN516x or JN517x Integrated Peripherals API, described in the *JN516x Integrated Peripherals API User Guide (JN-UG-3087)* or *JN517x Integrated Peripherals API User Guide (JN-UG-3118)*.
- **Hardware Reset:** When in Deep Sleep mode, the device can be woken by a hardware reset.

The valid wake sources for the different low-power modes are summarised in Table 1 below.

On leaving low-power mode, the Power Manager will call the user-defined callback function that has been registered using **PWRM_vRegisterWakeupCallback()**.

Low-Power Mode	Wake Source					
	Any Interrupt	Wake Timer	DIO	Comparator	Pulse Counter	Hardware Reset
Doze mode	✓	×	×	×	×	×
Sleep mode with oscillator running and memory held	×	✓	✓	✓	✓	×
Other Sleep modes	×	×	✓	✓	✓	×
Deep Sleep mode	×	×	✓	×	×	✓

Table 1: Valid Wake Sources for Low-Power Modes

3.7 Scheduling Wake Events

Note: This section is only applicable to the sleep mode in which the 32-kHz oscillator is left running and memory is held.

In **PWRM_vInit()**, if you have selected the Sleep mode with the 32-kHz oscillator running and memory held, you can schedule wake events which ensure that the device will be awake at certain times - that is, if the device is sleeping, it will be woken at the scheduled time. This scheduling uses Wake Timer 1 of the JN51xx device, which operates at 32 kHz.

A wake event can be scheduled using the function **PWRM_eScheduleActivity()**. This function requires you to specify the number of ticks of the wake timer until the wake event. You must also specify the user-defined callback function that must be called when the wake event occurs.

When the wake timer expires for a scheduled wake event, an interrupt is generated. The application's interrupt handler then calls the pre-defined callback function **PWRM_WakeInterruptCallback()**. This function maintains the list of scheduled wake events and, if necessary, re-starts the wake timer for the next scheduled wake event. The function also calls the user-defined callback function specified through **PWRM_eScheduleActivity()**.

Note: In addition, when the device wakes from sleep, the user-defined callback function registered through **PWRM_vRegisterWakeupCallback()** will also be called. However, this is a general-purpose wake-up function which is called irrespective of how the device was woken (it is not unique to scheduled wake events, but also called for external wake events).

3.8 Doze Mode

Doze mode is a lighter power-saving mode than the sleep modes, as all elements of the JN51xx device remain powered but the CPU is paused (CPU clock is stopped).

This low-power mode cannot be explicitly selected in **PWRM_vInit()**. The Power Manager will put the JN51xx device into Doze mode only in certain circumstances, described in Section 3.8.1 below. However, to enter Doze mode, the Power Manager must have been initialised using **PWRM_vInit()** and the power-saving modes must have been enabled using **PWRM_vManagePower()**.

3.8.1 Circumstances that Lead to Doze Mode

Although Sleep and Deep Sleep modes cannot be entered while there are activities running that must not be interrupted by sleep (see Section 3.5), the Power Manager can put the device into Doze mode while the activity counter is non-zero.

Even when the activity counter is zero, if a sleep mode has been configured with the 32-kHz oscillator running (see Section 3.3) but no wake event has been scheduled (see Section 3.6), the Power Manager will put the device into Doze mode instead of Sleep mode.

The decision to put a device into a Sleep mode or Doze mode is illustrated in the flowchart in Figure 2 below.

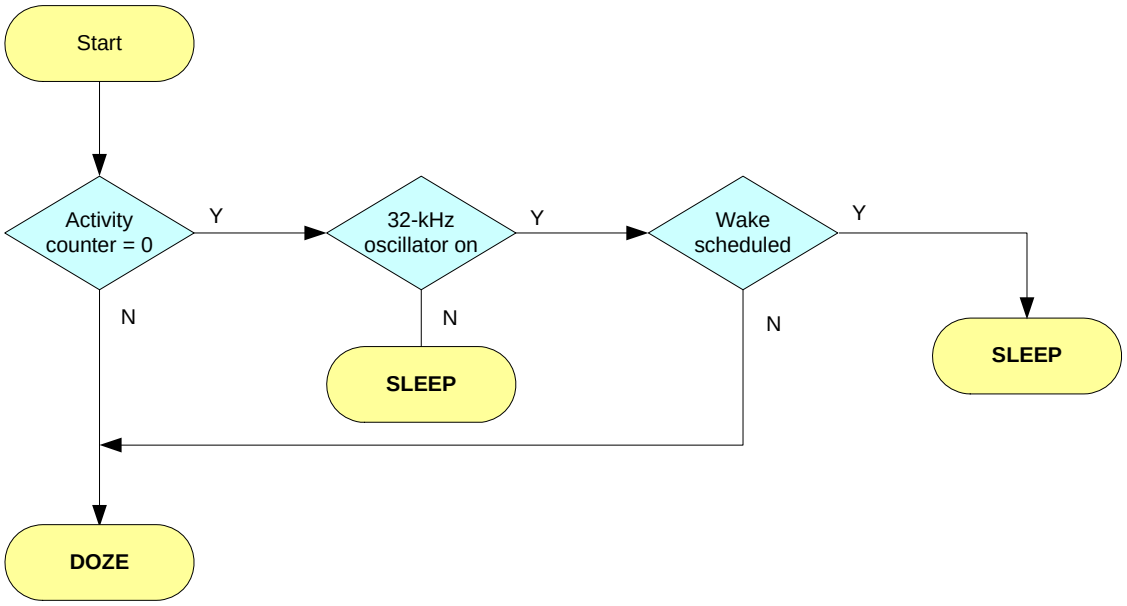

Figure 2: Flowchart of Decision to Enter Doze Mode

3.8.2 Doze Mode Monitoring During Development

Depending on the circumstances described in Section 3.8.1, the JN51xx device may spend a significant proportion of its time in Doze mode. The Power Manager API provides a function that allows you to investigate the fraction of time that the JN51xx device typically spends in Doze mode for a given application. The function provides a doze monitoring output on the DIO1 pin of the JN51xx device. This functionality can be used when the application is running in debug mode.

The function **PWRM_vSetupDozeMonitor()** must be called to start a monitoring session. The state of the DIO1 pin will then reflect the doze state of the device, allowing you to make doze state measurements using external equipment. The fraction of time that the JN51xx device spends in Doze mode can then be estimated as (see Figure 3): *Total time in Doze mode during session / Elapsed time of session*

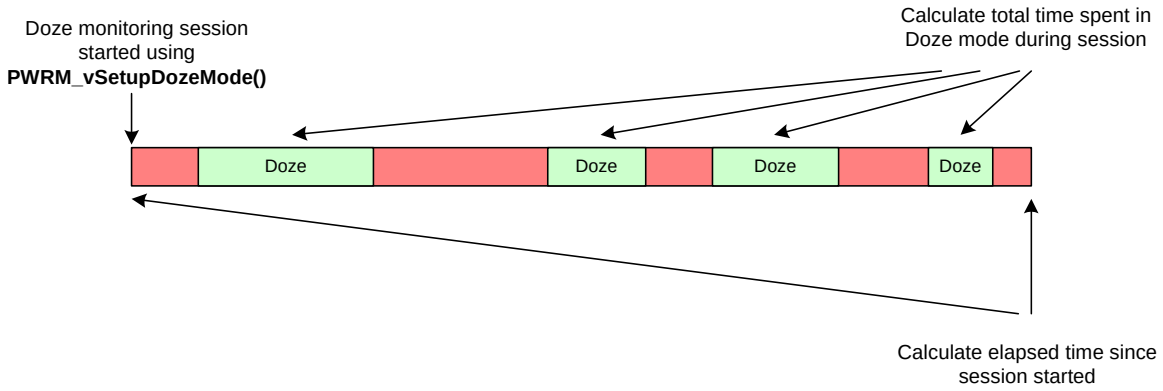

Figure 3: Doze Monitoring

To obtain sensible results, doze monitoring should be allowed to run for a significant period of time.

4. Protocol Data Unit Manager (PDUM)

Communication between nodes in a wireless network is implemented using messages which contain application data. The part of a message which contains this data is called the Application Protocol Data Unit (APDU). The Protocol Data Unit Manager (PDUM) is concerned with APDU memory management, and assembling and disassembling APDUs - that is, inserting data into APDUs to be transmitted and extracting data from received APDUs.

The Protocol Data Unit Manager (PDUM) is intended for use with ZigBee PRO applications.

4.1 Message Assembly and Disassembly

A message travels over a wireless network as a packet (usually an 802.15.4 packet) containing application data surrounded by header and footer information relating to the different layers of the protocol stack.

A message to be sent is prepared at the application level, at the top of the protocol stack, by creating an Application Protocol Data Unit (APDU) containing the application data to be included in the message. This APDU is then passed down the layers of the stack, with each layer adding its own protocol information to the header and footer. On reaching the 'physical' layer at the bottom of the stack, the message is complete and ready to be transmitted.

For transmission, the message is converted to an NPDU (Network Protocol Data Unit). If the length of the message is greater than the packet size used in network communication (e.g. 802.15.4 packet size), the message is divided up and transmitted in multiple NPDUs (Network Protocol Data Units). You will need to be aware of this if using a sniffer to detect transmitted packets.

Note: Data is stored in memory in the JN51xx device in big-endian byte order but is transmitted over the network in little-endian byte order.

A received message is passed up the protocol stack, with each stack layer stripping out the corresponding protocol information from the header and footer. On reaching the application level, only the APDU remains. The application data can then be extracted from this APDU.

The assembly and disassembly of a message, described above, are illustrated in the figure below, in which the lower stack layers (MAC and Physical) are provided by the IEEE 802.15.4 protocol.

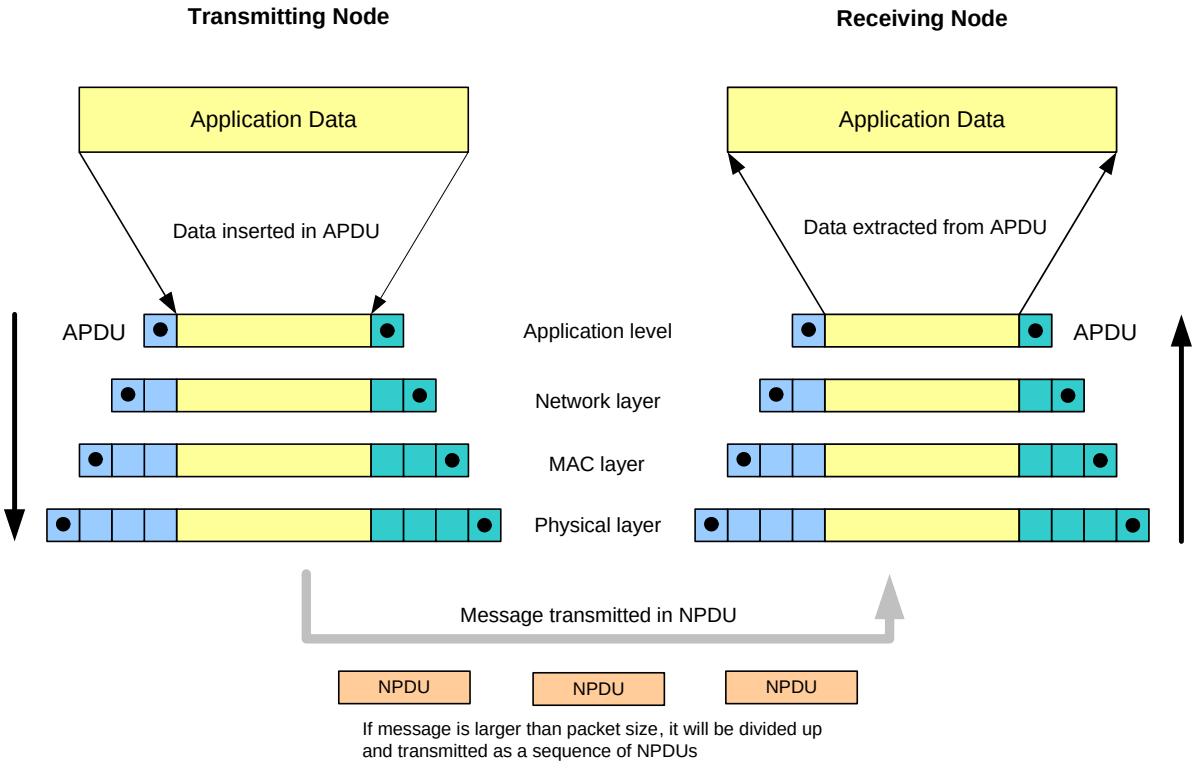

Figure 4: Message Assembly and Disassembly

4.2 Preparing the PDU Manager

In order to use the PDU Manager:

- You must statically define the required APDUs using the ZPS Configuration Editor (described in the *ZigBee 3.0 Stack User Guide (JN-UG-3113)*). Each APDU is given a unique handle. While the data payload of an APDU can be of arbitrary length, a maximum length is set for an APDU.
- Before calling any other PDUM functions in your code, you must call the function **PDUM_vInit()** to initialise the PDU Manager.

4.3 Inserting Data into Outgoing Message

When sending a message to another node, you must first create an APDU containing the application data to be sent. To do this, first allocate an APDU instance by calling the function **PDUM_hAPduAllocateAPduInstance()** and then populate the APDU instance with data using **PDUM_u16APduInstanceWriteNBO()**, in which you must specify:

- the handle of the APDU instance in which data is to be inserted (this is the handle returned by **PDUM_hAPduAllocateAPduInstance()**)
- the starting position of the data in the APDU - that is, the position of the least significant data byte
- the format of the data payload - the data can be made up of a sequence of data values of different types
- the data values to be inserted in the data payload

Alternatively, the function **PDUM_u16APduInstanceWriteStrNBO()** can be used to populate the APDU instance - this function allows a data structure to be inserted into the APDU.

You must then use the relevant ZigBee PRO API function to send the message - refer to the *ZigBee 3.0 Stack User Guide (JN-UG-3113)*. Once the message has been sent, the ZigBee PRO stack automatically de-allocates the memory-space used for the APDU instance.

Note that **PDUM_u16APduInstanceWriteNBO()** performs the necessary data conversion from big-endian byte order to little-endian byte order for transmission.

Alternatively, you can produce your own code to insert data into the payload of an APDU. To help you, two functions are provided:

- **PDUM_pvAPduInstanceGetPayload()**: This function returns a pointer to the start of the payload section of the APDU instance.
- **PDUM_eAPduInstanceSetPayloadSize()**: This function sets the size, in bytes, of the data payload.

Caution: *Data must be stored in memory in big-endian order but is transmitted over the network in little-endian byte order. Therefore, if you use your own code to insert data into an APDU, you must reverse the byte order of the data before inserting it. Failure to change the endianness of the data will result in an alignment exception.*

4.4 Extracting Data from Incoming Message

The function **PDUM_u16APduInstanceReadNBO()** provides an easy way of extracting the data payload from an incoming message. The **PDUM_u16APduInstanceReadNBO()** function requires the following to be specified:

- the handle of the APDU instance containing the data to be extracted (this is the handle contained in the ZPS_EVENT_AF_DATA_INDICATION stack event which notified the application of the arrival of the data message)
- the starting position of the data in the APDU - that is, the position of the least significant data byte
- the format of the data payload - the data can be made up of a sequence of data values of different types
- a pointer to a structure in which the extracted data will be stored

Once the data has been extracted, you should de-allocate the memory space used for the APDU instance by calling the function **PDUM_eAPduFreeAPduInstance()**.

Note that **PDUM_u16APduInstanceReadNBO()** performs the necessary data conversion from little-endian byte order to big-endian byte order for storage.

Alternatively, you can produce your own code to extract the payload data from an APDU. To help you, two functions are provided:

- **PDUM_pvAPduInstanceGetPayload()**: This function returns a pointer to the start of the payload data in the APDU instance.
- **PDUM_u16APduInstanceGetPayloadSize()**: This function returns the size, in bytes, of the data payload.

Caution: *Data is received from the network in little-endian byte order, but must be stored in memory in big-endian order. Therefore, if you use your own code to extract data from an APDU, you must reverse the byte order of the data before storing it. Failure to change the endianness of the data will result in an alignment exception.*

5. Debug (DBG) Module

This chapter describes the Debug (DBG) module which allows application code to be debugged by means of diagnostic messages that are output to a display device.

5.1 Overview

The Debug module comprises an API containing diagnostic functions that can be embedded in your application code. Application debugging using the Debug module requires the JN51xx device to be connected to a display device (such as a PC) via an IO interface, such as one of the on-chip UARTs. The display device must provide a dumb terminal through which output from the JN51xx device can be viewed. A typical implementation is illustrated in the figure below.

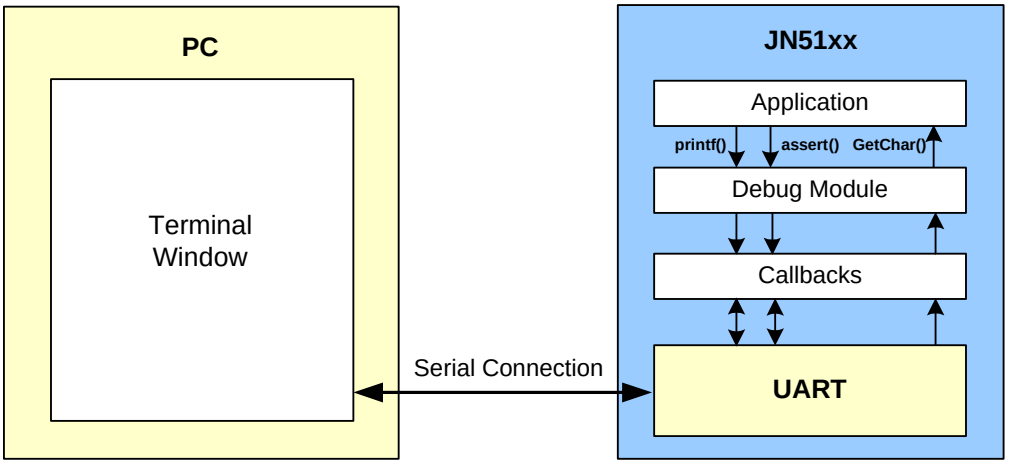

Figure 5: Typical Hardware Set-Up for Debugging

The API provides the essential printf- and assert-style debug functions, which can be strategically placed in your code:

- **DBG_vPrintf()** is used to output formatted strings and data values at an appropriate point during program execution, in order to indicate progress.
- **DBG_vAssert()** is used to test a logical condition, and to stop program execution if the test fails (condition is FALSE).

User-specified callback functions are used by the Debug module to control the IO interface (see Section 5.3).

The terminal on the PC can also supply input to the JN51xx UART. The function **DBG_iGetChar()** can be used by the application to obtain a character from this input source. This input can then be handled by the JN51xx application.

5.2 Enabling the Debug Module

The Debug module API is defined in the header file **DBG.h**, which must be included in your code.

In order to use the Debug module, it must be explicitly enabled at build time by defining DBG_ENABLE in the build - for example, by adding -DDBG_ENABLE to the compiler. If the module is not enabled in this way, all the Debug functions embedded in your code will be ignored.

In addition, the functions **DBG_vPrintf()** and **DBG_vAssert()** each include a Boolean parameter which can be used to enable/disable individual instances of these functions. Two or more instances of these functions can be grouped to form a 'stream' for which this Boolean parameter is a common constant used to enable/disable the whole function group. This constant can be set at build time (see Section 5.5).

Tip: By default, the Debug module will display each 'printf line' as passed. However, if DBG_VERBOSE is defined at build time then each line displayed will be prefixed with the file name and line number of the debug statement.

5.3 Initialising and Configuring the Debug Module

The way that the Debug module is configured and initialised depends on the serial IO interface which is to be used to output debug information from the JN51xx device to the attached PC:

- If a JN51xx UART is to be used for output, the required initialisation/ configuration is as described in Section 5.3.1. This option will be taken by most users.
- If any other serial IO interface is to be used for output, the required initialisation/ configuration is as described in Section 5.3.2.

Flags are provided in the global variable *DBG_u32Flags* for configuring certain aspects of the Debug module - for details, refer to Section 5.4.

5.3.1 Using JN51xx UART Input/Output

When a JN51xx UART is to be used for the input/output of debug information, the configuration and initialisation of the Debug module is accomplished with a single call to the function **DBG_vUartInit()**, which allows selection of the UART (0 or 1) and the baud-rate to be used. This function is used both during a cold start of the JN51xx device and during a warm start (where the latter is a device re-start with memory contents retained).

5.3.2 Using Alternative Serial Output

When an alternative to an on-chip UART is to be used for the output of debug information, the required IO interface must first be configured and enabled (using the relevant functions from the JN516x or JN517x Integrated Peripherals API).

The Debug module must then be initialised using the function **DBG_vInit()**. This function is used both during a cold start of the JN51xx device and during a warm start (where the latter is a device re-start with memory contents retained). The function takes as input a structure which contains pointers to four callback functions needed for debugging:

```
typedef struct
  {
   void (*prInitHardwareCb)(void);
   void (*prPutchCb)       (char c);
   void (*prFlushCb)       (void);
   void (*prFailedAssertCb)(void);
} tsDBG_FunctionTbl;
```

The callback functions are user-defined and are described in the table below.

Pointer	Callback Function
**prInitHardwareCb*	Function which re-initialises the IO interface after a warm start, e.g. when JN51xx device wakes from sleep.
**prPutchCb*	Function used by **DBG_vPrintf()** to output a single character to the IO interface.
**prFlushCb*	Function used by **DBG_vPrintf()** to flush the IO interface buffer to allow buffered output characters to be displayed. If the output is unbuffered, this function should do nothing or wait for the last character output using the **putch()** function to be made available. Note that the function should not append a newline character, as this should be handled by the formatting string passed to **DBG_vPrintf()**.
**prFailedAssertCb*	Function which is called when **DBG_vAssert()** fails. The function should stop execution and may reset the device.

Table 2: Callback Functions Specified in DBG_vInit()

5.4 Debug Configuration Flags

The Debug module has a global variable *DBG_u32Flags* which is a bitmap containing configuration flags. The bits/flags are enumerated, and are listed and described in the table below.

Flag/Enumeration	Description (if flag is set)
DBG_FLAG_NONE	None of the flags are set
DBG_FLAG_OUTGOING_NL_CRNL	Every \n character in the outgoing string is sent as \r\n. This is for compatibility with certain terminal programs.
DBG_FLAG_AUTO_FLUSH	**DBG_vFlush()** is called at the end of each **DBG_vPrintf()** invocation. The application may instead choose to flush the outgoing characters in idle time rather than at the end of each outputted string.
DBG_FLAG_FLUSH_WHEN_FULL	If the DBG back-end buffers outgoing characters then it will automatically flush the buffer when full. Otherwise, characters that do not fit in the buffer may be lost.

Table 3: Debug Configuration Flags

Note: The flags DBG_FLAG_OUTGOING_NL_CRNL and DBG_FLAG_AUTO_FLUSH are set by default.

5.5 Example Diagnostic Code

The following code fragment illustrates use of the Debug module API. The JN51xx UART 0 is used. Two debug 'streams' (1 and 2) are used to separately enable/disable two groups of debug lines.

```
#include <jendefs.h>
#include "DBG.h"
#include "DBG_Uart.h"

#ifndef DBG_STREAM_1
#define DBG_STREAM_1 FALSE
#endif

#ifndef DBG_STREAM_2
#define DBG_STREAM_2 FALSE
#endif

void appColdStart(void)
{
int i = 0;

/* Initialise the standard UART hardware */
DBG_vUartInit(DBG_E_UART_0, DBG_E_UART_BAUD_RATE_115200);

/* Now we can use DBG_vPrintf() and DBG_vAssert() to output characters
   to the UART device */
DBG_vPrintf(DBG_STREAM_1, "Printing to stream 1\n");
DBG_vPrintf(DBG_STREAM_2, "Printing an integer %i to stream 2\n", 10);
DBG_vAssert(DBG_STREAM_1, i == 1);
}
```

When building this application, you have following options:

- Debug disabled (the default)
- Debug enabled only for stream 1 - build with:

  `-DDBG_ENABLE -DDBG_STREAM_1=TRUE`
- Debug enabled only for stream 2 - build with:

  `-DDBG_ENABLE -DDBG_STREAM_2=TRUE`
- DBG enabled for both streams - build with:

  `-DDBG_ENABLE -DDBG_STREAM_1=TRUE -DDBG_STREAM_2=TRUE`

Part II:
Reference Information

6. PDM API

This chapter details the functions of the Persistent Data Manager (PDM) API that supports context data and application data saving in Non-Volatile Memory (NVM). For the JN516x and JN517x devices, this memory is internal EEPROM and this chapter will therefore refer to EEPROM.

The API is defined in the header file **pdm.h** and is divided into the following categories:

- EEPROM PDM functions - see Section 6.1
- EEPROM PDM Bitmap Counter functions - see Section 6.2
- EEPROM PDM miscellaneous functions - see Section 6.3

Note: For more information on how to use the functions described in this chapter, refer to Chapter 2.

6.1 EEPROM PDM Functions

The EEPROM PDM functions are listed below, along with their page references:

Note: For a description of how to use these functions, refer to Section 2.3.

PDM_eInitialise

```
PDM_teStatus PDM_eInitialise(
                uint8 u8NumberOfEEPROMsegments
#ifndef PDM_NO_RTOS
                ,
                OS_thMutex hPdmMutex
#endif);
```

Description

This function initialises the PDM module and registers the required PDM functions. It must be called during both a warm start and a cold start.

The function initialises the PDM environment and builds the underlying EEPROM file system. A RAM-based file system is created to allow the PDM to map data to/from the EEPROM. The EEPROM sectors are scanned for evidence of any valid user data, which is mapped into the RAM file system. This routine handles any write errors that may have occurred if the EEPROM was powered down whilst data was being written to the PDM system. Once the file system has been constructed, you can then write data to and read data from the EEPROM via PDM.

The PDM can operate within any number of EEPROM segments, as specified through the parameter *u8NumberOfEEPROMsegments*. However, if a zero value is specified for this parameter, the function will auto-configure the PDM by interrogating the JN516x/7x chip to obtain the variant and scaling the PDM accordingly, giving the application access to the full EEPROM.

An optional mutex can be specified in order to serialise PDM function calls. If specified, this mutex is automatically applied during a PDM function call to prevent concurrent calls. Note that:

- The mutex is not available when using the PDM in applications developed with a ZigBee 3.0 SDK (JN-SW-4170 or JN-SW-4270) or the IEEE802.15.4 SDK (JN-SW-4163), in which case the flag PDM_NO_RTOS must be defined in the makefile - the function parameter *hPdmMutex* is then disabled.
- The mutex is always implemented when using the PDM in applications developed with the JenNet-IP SDK (JN-SW-4165), in which case the function parameter *hPdmMutex* must be set to a non-zero value.

For more information on using the PDM without the RTOS, refer to Section 2.2.

Parameters

u8NumberOfEEPROMsegments
: Number of contiguous EEPROM sectors to be managed. A zero value indicates that the full EEPROM should be used.

hPdmMutex
: Optional handle of the mutex to be used to serialise PDM calls

Returns

PDM_E_STATUS_OK

PDM_E_STATUS_INTERNAL_ERROR

PDM_eSaveRecordData

```
PDM_teStatus PDM_eSaveRecordData(
                uint16 u16IdValue,
                uint8 *pu8DataBuffer,
                uint16 u16Datalength);
```

Description

This function saves the specified application data from RAM to the specified record in EEPROM. The record is identified by means of a 16-bit user-defined value.

Caution: *The application software must not use record identifier values that would clash with those used by the NXP libraries used with the application. The ZigBee PRO stack libraries use values above 0x8000. The JenNet-IP libraries use values between 0x3000 and 0x3007.*

When a data record is saved to the EEPROM for the first time, the data is written provided there are enough EEPROM segments available to hold the data. Upon subsequent save requests, if there has been a change between the RAM-based and EEPROM-based data buffers then the PDM will attempt to re-save only the segments that have changed (if no data has changed, no save will be performed). This is advantageous due to the restricted size of the EEPROM and the constraint that old data must be preserved while saving changed data to the EEPROM.

Provided that you have registered a callback function with the PDM (see Section 6.3), the callback mechanism will signal when a save has failed. Upon failure, the callback function will be invoked and pass the event E_PDM_SYSTEM_EVENT_DESCRIPTOR_SAVE_FAILED to the application.

Parameters

u16IdValue	User-defined ID of the record to be saved (see Caution above)
**pu8DataBuffer*	Pointer to data buffer to be saved in the record in EEPROM
u16Datalength	Length of data to be saved, in bytes

Returns

PDM_E_STATUS_OK (success)

PDM_E_STATUS_INVLD_PARAM (specified record ID is invalid)

PDM_E_STATUS_NOT_SAVED (save to EEPROM failed)

PDM_eReadDataFromRecord

```
PDM_teStatus PDM_eReadDataFromRecord(
                                uint16 u16IdValue,
                                void *pvDataBuffer,
                                uint16 u16DataBufferLength,
                                uint16 *pu16DataBytesRead);
```

Description

This function reads the specified record of application data from the EEPROM and stores the read data in the supplied data buffer in RAM. The record is specified using its unique 16-bit identifier.

Before calling this function, it may be useful to call **PDM_bDoesDataExist()** in order to determine whether a record with the specified identifier exists in the EEPROM and, if it does, to obtain its size.

Parameters

u16IdValue	User-defined ID of the record to be read
**pvDataBuffer*	Pointer to the data buffer in RAM where the read data is to be stored
u16DataBufferLength	Length of the data buffer, in bytes
**pu16DataBytesRead*	Pointer to a location to receive the number of data bytes read

Returns

PDM_E_STATUS_OK (success)

PDM_E_STATUS_INVLD_PARAM (specified record ID is invalid)

PDM_eDeleteData

PDM_teStatus PDM_eDeleteData(uint16 *u16IdValue***);**

Description

This function deletes the specified record of application data in EEPROM.

Alternatively, all records in EEPROM can be deleted using the function **PDM_eDeleteAllData()**.

Parameters

u16IdValue	User-defined ID of the record to be deleted

Returns

PDM_E_STATUS_OK (success)

PDM_E_STATUS_INVLD_PARAM (specified record ID is invalid)

PDM_eDeleteAllData

```
PDM_teStatus PDM_eDeleteAllData(void);
```

Description

This function deletes all records in EEPROM, including both application data and stack context data, resulting in an empty PDM file system. The EEPROM segment Wear Count values are preserved (and incremented) throughout this function call.

Caution: *You are not recommended to delete records of stack context data before a rejoin of the same secured network. If these records are deleted, data sent by the node after the rejoin will be rejected by the destination node since the frame counter has been reset on the source node. For more details, refer to "Application Design Notes" appendix in the ZigBee 3.0 Stack User Guide (JN-UG-3113).*

Alternatively, an individual record of application data can be deleted using the function **PDM_eDeleteData()**.

Parameters

None

Returns

None

PDM_u8GetSegmentCapacity

```
uint8 PDM_u8GetSegmentCapacity(void);
```

Description

This function returns the number of unused segments that remain in the EEPROM.

Parameters

None

Returns

Number of EEPROM segments free

PDM_u8GetSegmentOccupancy

```
uint8 PDM_u8GetSegmentOccupancy(void);
```

Description

This function returns the number of used segments in the EEPROM.

Parameters

None

Returns

Number of EEPROM segments used

PDM_bDoesDataExist

```
bool_t PDM_bDoesDataExist(uint16 u16IdValue,
                          uint16 *pu16DataLength);
```

Description

This function checks whether data associated with thd specified record ID exists in the EEPROM. If the data record exists, the function returns the data length, in bytes, in a location to which a pointer must be provided.

Parameters

u16IdValue	User-defined ID of the record to be found
***pu16DataLength**	Pointer to location to receive length, in bytes, of data record (if any) associated with specified record ID

Returns

TRUE if data record found, FALSE otherwise

6.2 EEPROM PDM Bitmap Counter Functions

The EEPROM PDM Bitmap Counter functions are listed below, along with their page references:

Note: For a description of how to use these functions, refer to Section 2.4.

PDM_eCreateBitmap

```
PDM_teStatus PDM_eCreateBitmap(uint16 u16IdValue,
                               uint32 u32InitialValue);
```

Description

The function creates a bitmap structure for a counter in a segment of the EEPROM. A user-defined ID and a start value for the bitmap counter must be specified.

The start value is stored in the counter's header. A bitmap is created to store the incremental value of the counter (over the start value). This bitmap can subsequently be incremented (by one) by calling the function **PDM_eIncrementBitmap()**. The incremental value stored in the bitmap and the start value stored in the header can be read at any time using the function **PDM_eGetBitmap()**.

If the specified ID value has already been used or the specified start value is NULL, the function returns PDM_E_STATUS_INVLD_PARAM. If the EEPROM has no free segments, the function returns PDM_E_STATUS_USER_PDM_FULL.

Parameters

u16IdValue	User-defined ID for bitmap counter to be created
u32InitialValue	Initial 32-bit value of bitmap counter

Returns

PDM_E_STATUS_OK (success)

PDM_E_STATUS_INVLD_PARAM (an invalid parameter value was supplied)

PDM_E_STATUS_PDM_FULL (there is no space to store this bitmap)

PDM_eIncrementBitmap

PDM_teStatus PDM_eIncrementBitmap(uint16 *u16IdValue***);**

Description

The function increments the bitmap value of the specified counter in the EEPROM. The counter must be identified using the user-defined ID value assigned when the counter was created using the function **PDM_eCreateBitmap()**.

The bitmap can be incremented within an EEPROM segment until its value saturates (contains all 1s). At this point, the function returns the code PDM_E_STATUS_SATURATED_OK. The next time that this function is called, the counter is automatically moved to a new segment (provided that one is available), the start value in its header is increased appropriately and the bitmap is reset to zero. To avoid increasing the segment Wear Count, the old segment is not formally deleted before a new segment is started. If the EEPROM has no free segments when the above overflow occurs, the function returns the code PDM_E_STATUS_USER_PDM_FULL.

If the specified ID value has already been used, the function returns PDM_E_STATUS_INVLD_PARAM.

Parameters

u16IdValue	User-defined ID of counter to be incremented

Returns

PDM_E_STATUS_OK (success)

PDM_E_STATUS_INVLD_PARAM (an invalid parameter value was supplied)

PDM_E_STATUS_PDM_FULL (no further EEPROM segments for the bitmap)

PDM_E_STATUS_BITMAP_SATURATED_OK (increment made but segment now saturated)

PDM_eGetBitmap

```
PDM_teStatus PDM_eGetBitmap(uint16 u16IdValue,
                            uint32 *pu32InitialValue,
                            uint32 *pu32BitmapValue);
```

Description

The function reads the specified counter value from the EEPROM. The counter must be identified using the user-defined ID value assigned when the counter was created using the function **PDM_eCreateBitmap()**. The function returns the counter's start value (from the counter's header) and incremental value (from the counter's bitmap).

The counter value is calculated as:

Start Value + Incremental Value

or in terms of the function parameters:

*****pu32InitialValue* + *****pu32BitmapValue*

Note that the start value may be different from the one specified when the counter was created, as the start value is updated each time the counter outgrows a segment and the bitmap is reset to zero.

This function should be called when the device comes up from a cold start, to check whether a bitmap counter is present in EEPROM.

If the specified ID value has already been used or a NULL pointer is provided for the received values, the function returns PDM_E_STATUS_INVLD_PARAM.

Parameters

u16IdValue	User-defined ID for bitmap counter to be accessed
*****pu32InitialValue*	Pointer to location to receive the start value of the counter
*****pu32BitmapValue*	Pointer to location to receive the incremetal value of the counter

Returns

PDM_E_STATUS_OK (success)

PDM_E_STATUS_INVLD_PARAM (an invalid parameter value was supplied)

PDM_eDeleteBitmap

PDM_teStatus PDM_eDeleteBitmap(uint16 *u16IdValue***);**

Description

This function deletes the specified counter in the EEPROM. The counter must be identified using the user-defined ID value assigned when the bitmap was created using the function **PDM_eCreateBitmap()**.

The function can be used to formally delete a counter. It clears the current segment occupied by the counter and also all the older (expired) segments used for the counter. This deletion increments the Wear Counts for these segments and should be done only if absolutely necessary, as the expired segments can be re-used directly via the PDM without formal deletion.

If the specified ID value does not exist in the PDM, the function returns PDM_E_STATUS_INVLD_PARAM.

Parameters

u16IdValue	User-defined ID for bitmap counter to be deleted

Returns

PDM_E_STATUS_OK (success)

PDM_E_STATUS_INVLD_PARAM (an invalid parameter value was supplied)

6.3 EEPROM PDM Miscellaneous Functions

The EEPROM PDM miscellaneous functions include a function for registering a user-defined PDM system callback function and functions related to the Wear Counts of EEPROM segments. The functions are listed below, along with their page references:

Note: For a description of how to use these functions, refer to Section 2.5.2 and Section 2.5.4.

PDM_vRegisterSystemCallback

```
void PDM_vRegisterSystemCallback(
                    PDM_tpfvSystemEventCallback
                        fpvPDM_SystemEventCallback);
```

Description

This function registers a user-defined callback function to handle PDM events and errors.

Parameters

fpvPDM_SystemEventCallback	Pointer to the application callback function. The function type **PDM_tpfvSystemEventCallback** is documented in Section . The events generated by the PDM library are documented in Section 10.1.3

Returns

None

PDM_vSetWearCountTriggerLevel

```
void PDM_vSetWearCountTriggerLevel(
                                uint32 u32WearCountTriggerLevel);
```

Description

This function sets the Wear Count value of an EEPROM segment at which a Wear Count event will be triggered and the PDM callback function will be activated. The invoked callback function is user-defined and is registered using the function **PDM_vRegisterSystemCallback()**.

The callback function will only be invoked once for a particular segment, when the specified Wear Count value occurs (it will not be invoked for every occurrence afterwards when the segment Wear Count exceeds the trigger value).

Parameters

u32WearCountTriggerLevel	Wear Count value that triggers a Wear Count event

Returns

None

PDM_eGetSegmentWearCount

```
PDM_teStatus PDM_eGetSegmentWearCount(
                                uint8 u8SegmentIndex,
                                uint32 *pu32WearCount);
```

Description

This function obtains the current Wear Count value of the specified EEPROM segment.

Parameters

u8SegmentIndex	Index of EEPROM segment for which Wear Count needed
pu32WearCount	Pointer to location to receive obtained Wear Count value

Returns

PDM_E_STATUS_OK (success)

PDM_E_STATUS_INVLD_PARAM (an invalid parameter value was supplied)

7. PWRM API

This chapter describes the functions of the Power Manager (PWRM) API. The API is defined in the header file **pwrm.h**.

Caution: *The Power Manager uses Wake Timer 1 of the JN51xx device if scheduled wake events are configured. In this case, do not use this wake timer for any other purpose in your application.*

The PWRM API functions are divided into the following categories:

- 'Core' functions, described in Section 7.1
- 'Callback Set-up' functions, described in Section 7.2
- 'Debugging' functions, described in Section 7.3

7.1 Core Functions

The PWRM core functions are listed below, along with their page references:

PWRM_vInit

void PWRM_vInit(PWRM_tePowerMode *ePowerMode***);**

Description

This function is used to initialise the Power Manager and specify the low-power mode in which the JN51xx device should be put when inactive.

There are five possible low-power modes that can be specified:

- Sleep with 32-kHz oscillator running and memory held
- Sleep with 32-kHz oscillator running and memory not held
- Sleep with 32-kHz oscillator not running and memory held
- Sleep with 32-kHz oscillator not running and memory not held
- Deep Sleep (32-kHz oscillator not running and memory not held)

The enumerations for the above power modes are listed below and described in Section 10.2.1. For further information on these low-power modes and how to wake from them, refer to Section 3.1.

Note that if the Power Manager is unable to put the JN51xx device into the specified low-power mode, it will put the device into Doze mode instead - see description of **PWRM_vManagePower()**.

If the 32-kHz oscillator is run, the JN51xx device's Wake Timer 1 is calibrated and made available (and then must not be used for any other purpose).

Parameters

ePowerMode	The power mode to be used during sleep, one of: PWRM_E_SLEEP_OSCON_RAMON PWRM_E_SLEEP_OSCON_RAMOFF PWRM_E_SLEEP_OSCOFF_RAMON PWRM_E_SLEEP_OSCOFF_RAMOFF PWRM_E_SLEEP_DEEP

Returns

None

PWRM_eStartActivity

```
PWRM_teStatus PWRM_eStartActivity(void);
```

Description

This function is used to notify the Power Manager that an activity has been started which must not be interrupted by sleep. Thus, while such an activity is running, the JN51xx device will not enter sleep mode.

The function **PWRM_eFinishActivity()** must then be called when the activity has completed. However, if **PWRM_eStartActivity()** has also been called for other activities that have not yet finished, the device will not be able to enter sleep mode until **PWRM_eFinishActivity()** has been called for all such activities.

The activity for which **PWRM_eStartActivity()** is called does not need to be identified, since the function simply increments a counter of running activities that must not be interrupted by sleep. There is an upper limit of 64K to the value of this counter. If this limit is exceeded, an overflow error is returned.

Parameters

None

Returns

PWRM_E_OK (success)

PWRM_E_ACTIVITY_OVERFLOW (activity counter limit exceeded)

PWRM_eFinishActivity

```
PWRM_teStatus PWRM_eFinishActivity(void);
```

Description

This function is used to notify the Power Manager that an activity has completed which was not to be interrupted by sleep.

The function call must be paired with a previous call to **PWRM_eStartActivity()**. Sleep mode cannot be entered until **PWRM_eFinishActivity()** has been called for all activities for which **PWRM_eStartActivity()** has been previously called.

The activity for which **PWRM_eFinishActivity()** is called does not need to be identified, since the function simply decrements a counter of running activities that must not be interrupted by sleep. Sleep mode must not be entered until this counter reaches zero. If this function is called when the counter is already zero, an underflow error is returned.

Parameters

None

Returns

PWRM_E_OK (success)

PWRM_E_ACTIVITY_UNDERFLOW (activity counter already zero)

PWRM_u16GetActivityCount

```
uint16 PWRM_u16GetActivityCount(void);
```

Description

This function obtains the current value of the activity counter which indicates the number of activities currently running that must not be interrupted by sleep. Sleep mode cannot be entered until the value of this counter is zero.

Parameters

None

Returns

Current value of activity counter

PWRM_eScheduleActivity

```
PWRM_teStatus PWRM_eScheduleActivity(
                    pwrm_tsWakeTimerEvent *psWake,
                    uint32 u32Ticks,
                    void (*prCallbackfn)(void));
```

Description

This function can be used to add a wake point and associated callback function to a list of scheduled wake points and callbacks. The new wake point is linked to an exclusive 32-kHz software wake timer, through the specified structure.

The function takes as input the number of ticks of the wake timer until the scheduled wake point. When the wake timer expires, the JN51xx device will be woken from sleep and the specified callback function will be called.

To use this function, the Power Manager must be configured through **PWRM_vInit()** to implement a low-power mode in which the 32-kHz oscillator is running and memory is held (otherwise, the list of scheduled wake points will be lost when the device enters sleep mode).

The function will return an error (see below) if the 32-kHz oscillator has not been configured to run during sleep or the software wake timer is already running for another wake point.

Parameters

***psWake**	Pointer to a structure to be populated with the wake point and callback function (see below)
u32Ticks	The number of ticks of the 32-kHz wake timer until wake point
***prCallbackfn**	Pointer to callback function associated with wake point

Returns

PWRM_E_OK (wake timer started successfully)

PWRM_E_TIMER_RUNNING (wake timer already running for another wake point)

PWRM_E_TIMER_INVALID (oscillator not configured to run during sleep)

PWRM_vManagePower

```
void PWRM_vManagePower(void);
```

Description

This function instructs the Power Manager to manage the power state of the JN51xx device. The device must be idle when this function is called, i.e. the function is typically called from the OS idle task.

Once this function has been called, whenever appropriate, the Power Manager will put the device into the low-power mode specified through the function **PWRM_vInit()**. To allow the device to enter sleep mode:

- No activities that are uninterruptable by sleep must be running - that is, the activity counter must be zero.
- If the 32-kHz oscillator will run during sleep, a wake point must have been scheduled using **PWRM_vScheduleActivity()** (this condition does not apply when the oscillator is not used)

If the above two conditions are not satisfied, the function will put the device into Doze mode instead of sleep mode. Doze mode simply pauses the on-chip CPU, leaving all components powered (e.g. radio), and requires an interrupt to be configured to wake the device.

Before putting the device into sleep mode, this function calls any user-defined callback functions that have been registered using the function **PWRM_vRegisterPreSleepCallback()**.

Parameters

None

Returns

None

7.2 Callback Set-up Functions

The PWRM callback set-up functions are used to introduce user-defined callback functions that must be defined when using the Power Manager.

The functions are listed below, along with their page references:

vAppMain

```
void vAppMain(void);
```

Description

This is a user-defined callback function which is the application entry point when using the Power Manager. This function should never return.

Parameters

None

Returns

None

PWRM_vRegisterPreSleepCallback

```
void PWRM_vRegisterPreSleepCallback(
                    tsCallbackDescriptor *psCBDesc);
```

Description

This function is used to register a user-defined callback function that will be called by the Power Manager before the JN51xx device enters sleep mode. You must specify a pointer to a structure containing a descriptor for your callback function.

The callback function must have been declared using the macro **PWRM_CALLBACK(***fn_name***)**, where *fn_name* is the name of the callback function.

The callback descriptor must have been declared using the macro **PWRM_DECLARE_CALLBACK_DESCRIPTOR(***desc_name***,** *fn_name***)**, where *desc_name* is the descriptor name and *fn_name* is the callback function name.

For example:

```
PWRM_CALLBACK(vPreSleepCB1);
PWRM_DECLARE_CALLBACK_DESCRIPTOR(pscb1_desc, vPreSleepCB1);
```

The callback function should perform any housekeeping tasks that are necessary before the device enters sleep mode.

Note that this registration function is normally called within the user-defined function **vAppRegisterPWRMCallbacks()**. This ensures that the callback is registered during a cold start.

Parameters

***psCBDesc**	Pointer to callback descriptor structure

Returns

None

PWRM_vRegisterWakeupCallback

```
void PWRM_vRegisterWakeupCallback(
                    tsCallbackDescriptor *psCBDesc);
```

Description

This function is used to register a user-defined callback function that will be called by the Power Manager when the JN51xx device wakes from sleep (this may be due to a change on a DIO line or comparator input, or the expiry of a wake timer). You must specify a pointer to a structure containing a descriptor for your callback function.

The callback function must have been declared using the macro **PWRM_CALLBACK(***fn_name***)**, where *fn_name* is the name of the callback function.

The callback descriptor must have been declared using the macro **PWRM_DECLARE_CALLBACK_DESCRIPTOR(***desc_name***,** *fn_name***)**, where *desc_name* is the descriptor name and *fn_name* is the callback function name.

For example:

```
PWRM_CALLBACK(vWakeUpCB1);
PWRM_DECLARE_CALLBACK_DESCRIPTOR(wucb1_desc, vWakeUpCB1);
```

The callback function should perform any housekeeping tasks that are necessary after the device wakes from sleep.

Note that this registration function is normally called within the user-defined function **vAppRegisterPWRMCallbacks()**. This ensures that the callback is registered during a cold start.

Parameters

***psCBDesc**	Pointer to callback descriptor structure

Returns

None

vAppRegisterPWRMCallbacks

```
void vAppRegisterPWRMCallbacks(void);
```

Description

This is a user-defined function to register pre- and post-sleep callback functions, if required.

The function definition must itself use **PWRM_vRegisterPreSleepCallback()** and **PWRM_vRegisterWakeupCallback()** to register the required callbacks.

Parameters

None

Returns

None

PWRM_vWakeInterruptCallback

```
void PWRM_vWakeInterruptCallback(void);
```

Description

This function is a pre-defined callback function which must be called from the application's interrupt handler to deal with interrupts from Wake Timer 1 on the JN51xx device.

The function is needed to maintain the scheduled wake points list, by restarting the wake timer for the next wake-up event (if any) when the previous one has just completed. The function also calls the user-defined callback function specified through **PWRM_vScheduleActivity()**.

Parameters

None

Returns

None

7.3 Debugging Function

The PWRM debugging function can be used to investigate how long the JN51xx device spends in Doze mode. The Doze state is output on the JN51xx DIO1 pin for external monitoring, allowing you to calculate the proportion of time that the device typically spends in Doze mode for a given application.

The function is listed below, along with its page reference:

PWRM_vSetupDozeMonitor

```
void PWRM_vSetupDozeMonitor(bool_t bUseIO);
```

Description

This function can be used during debug to start a Doze mode monitoring session on the JN51xx device - that is, to investigate the proportion of the time that the device typically spends in Doze mode.

The Doze state of the device is output on the pin DIO1. This allows the times spent in and out of Doze mode to be measured externally.

Parameters

bUseIO	Always set to TRUE

Returns

None

8. PDUM API

This chapter describes the functions of the Protocol Data Unit Manager (PDUM) API. The API is defined in the header file **pdum.h**.

The PDUM API functions are listed below, along with their page references:

Note: In ZigBee PRO, the APDUs used by the application must be pre-defined (before building the application) using the ZPS Configuration Editor. This tool is detailed in the *ZigBee 3.0 Stack User Guide (JN-UG-3113)*.

PDUM_vInit

```
void PDUM_vInit();
```

Description

This function initialises the PDU Manager and must therefore be the first PDUM function called.

Parameters

None

Returns

None

PDUM_hAPduAllocateAPduInstance

```
PDUM_thAPduInstance
PDUM_hAPduAllocateAPduInstance(
                    PDUM_thAPdu hAPdu);
```

Description

This function allocates an instance of an Application Protocol Data Unit (APDU) - that is, memory space is allocated to the APDU instance.

The available APDUs (types and their handles) are pre-defined using the ZPS Configuration Editor (refer to the *ZigBee 3.0 Stack User Guide (JN-UG-3113)*).

The allocated APDU instance can subsequently be populated with data and sent to another node.

Parameters

hAPdu	Handle of APDU (type)

Returns

Handle of allocated APDU instance

PDUM_INVALID_HANDLE if no APDU instances free

PDUM_eAPduFreeAPduInstance

```
PDUM_teStatus PDUM_eAPduFreeAPduInstance(
                    PDUM_thAPduInstance hAPduInst);
```

Description

This function de-allocates the specified APDU instance, thus freeing the associated memory space.

Parameters

hAPduInstance Handle of APDU instance

Returns

PDUM_E_INTERNAL_ERROR

PDUM_u16APduInstanceReadNBO

```
uint16 PDUM_u16APduInstanceReadNBO(
                PDUM_thAPduInstance hAPduInst,
                uint16 u16Pos,
                const char *szFormat,
                void *pvStruct);
```

Description

This function reads data from the specified APDU instance and inserts the data into a C structure. The byte position of the start (least significant byte) of the data in the APDU instance must be specified, as well as the format of the data.

Data is read from the APDU instance in packed network byte order (little-endian) and translated into unpacked host byte order for the C structure (big-endian for the JN51xx device).

Parameters

hAPduInst	Handle of APDU instance to read the data from
u32Pos	The starting position (least significant byte) of the data within the APDU
**szFormat*	Format string of the data: b 8-bit byte h 16-bit half-word (short integer) w 32-bit word l 64-bit long-word (long integer) a\xnn nn (hex) bytes of data (array) p\xnn nn (hex) bytes of packing
***pvStruct*	Pointer to C structure to receive the data

Note that the compiler will not correctly interpret the format string “a\xnnb” for a data array followed by a single byte, e.g. “a\x0ab”. In this case, to ensure that the ‘b’ (for byte) is not interpreted as a hex value, use the format “a\xnn” “b”, e.g. “a\x0a” “b”.

Returns

Total number of data bytes read from the APDU instance

PDUM_u16APduInstanceWriteNBO

```
uint16 PDUM_u16APduInstanceWriteNBO(
                PDUM_thAPduInstance hAPduInst,
                uint16 u16Pos,
                const char *szFormat, ...);
```

Description

This function writes the specified data values into the specified APDU instance. The byte position of the start of the data (least significant byte) in the APDU instance must be specified, as well as the format of the data.

The data values are written into the APDU instance at the specified position in packed network byte order (little-endian). The input data values should be in host byte order (big-endian for the JN51xx device).

Parameters

hAPduInst	Handle of the APDU instance to write the data into
u32Pos	The starting position (least significant byte) of the data within the APDU instance
**szFormat*	Format string of the data: b 8-bit byte h 16-bit half-word (short integer) w 32-bit word l 64-bit long-word (long integer) a\xnn nn (hex) bytes of data (array) p\xnnnn (hex) bytes of packing
...	Variable list of data values described by the format string

Note that the compiler will not correctly interpret the format string “a\xnnb” for a data array followed by a single byte, e.g. “a\x0ab”. In this case, to ensure that the ‘b’ (for byte) is not interpreted as a hex value, use the format “a\xnn” “b”, e.g. “a\x0a” “b”.

Returns

Total number of bytes written to the APDU instance

PDUM_u16APduInstanceWriteStrNBO

```
uint16 PDUM_u16APduInstanceWriteStrNBO(
                PDUM_thAPduInstance hAPduInst,
                uint16 u16Pos,
                const char *szFormat,
                void *pvStruct);
```

Description

This function writes data from the specified structure into the specified APDU instance. The byte position of the start of the data (least significant byte) in the APDU instance must be specified, as well as the format of the data.

The data values are written into the APDU instance at the specified position in packed network byte order (little-endian). The input data values should be in host byte order (big-endian for the JN51xx device).

Parameters

hAPduInst	Handle of the APDU instance to write the data into
u32Pos	The starting position (least significant byte) of the data within the APDU instance
**szFormat*	Format string of the data: b 8-bit byte h 16-bit half-word (short integer) w 32-bit word l 64-bit long-word (long integer) a\xnn nn (hex) bytes of data (array) p\xnnnn (hex) bytes of packing
***pvStruct*	Pointer to C structure to containing data

Note that the compiler will not correctly interpret the format string “a\xnnb” for a data array followed by a single byte, e.g. “a\x0ab”. In this case, to ensure that the ‘b’ (for byte) is not interpreted as a hex value, use the format “a\xnn” “b”, e.g. “a\x0a” “b”.

Returns

Total number of bytes written to the APDU instance

PDUM_u16SizeNBO

uint16 PDUM_u16SizeNBO(const char ****szFormat*);**

Description

This function obtains the size, in bytes, of an APDU data payload, given the format of the data.

Parameters

**szFormat*	Format string of the data: b 8-bit byte h 16-bit half-word (short integer) w 32-bit word l 64-bit long-word (long integer) a\xnn nn (hex) bytes of data (array) p\xnnnn (hex) bytes of packing

Note that the compiler will not correctly interpret the format string “a\xnnb” for a data array followed by a single byte, e.g. “a\x0ab”. In this case, to ensure that the ‘b’ (for byte) is not interpreted as a hex value, use the format “a\xnn” “b”, e.g. “a\x0a” “b”.

Returns

Number of bytes in data payload

PDUM_u16APduGetSize

uint16 PDUM_u16APduGetSize(PDUM_thAPdu *hAPdu***);**

Description

This function obtains the maximum size, in bytes, of the specified APDU (type).

Parameters

hAPdu Handle of APDU

Returns

Number of bytes in APDU

PDUM_pvAPduInstanceGetPayload

```
void * PDUM_pvAPduInstanceGetPayload(
                    PDUM_thAPduInstance hAPduInst);
```

Description

This function obtains a pointer to the payload data of the specified APDU instance.

Parameters

hAPduInst	Handle of APDU instance to access

Returns

Pointer to data as an array of bytes

PDUM_u16APduInstanceGetPayloadSize

```
uint16 PDUM_u16APduInstanceGetPayloadSize(
                    PDUM_thAPduInstance hAPduInst);
```

Description

This function obtains the size, in bytes, of the payload data of the specified APDU instance.

Parameters

hAPduInst	Handle of APDU instance to access

Returns

Size of the payload data, in bytes

PDUM_eAPduInstanceSetPayloadSize

```
PDUM_teStatus PDUM_eAPduInstanceSetPayloadSize(
                    PDUM_thAPduInstance hAPduInst,
                    uint16 u16Size);
```

Description

This function sets the size, in bytes, of the payload of the specified APDU instance.

Parameters

hAPduInst	Handle of APDU instance
u16Size	Size of payload to set, in bytes

Returns

PDUM_OK
PDUM_E_APDU_INSTANCE_TOO_BIG

PDUM_vDBGPrintAPduInstance

```
void PDUM_vDBGPrintAPduInstance(
                    PDUM_thAPduInstance hAPduInst);
```

Description

This function can be used to output the specified APDU instance via the Debug (DBG) module.

For details of the DBG functions, refer to Chapter 8.

Parameters

hAPdu	Handle of APDU instance to output

Returns

None

9. DBG API

The chapter describes the functions of the Debug (DBG) module API. The API is defined in the header file **dbg.h**.

To use the Debug module, it must be enabled at build-time by defining DBG_ENABLE in the build - for example, by adding the -DDBG_ENABLE option to the compiler.

By default, the Debug module will just display each line as passed. However, if DBG_VERBOSE is defined at build-time then each line displayed will be prefixed with the file name and line number of the debug statement.

Note: Compiling with the DBG option results in a larger application size, requiring a lot more space in RAM.

The DBG API functions are listed below, along with their page references:

DBG_vInit

void DBG_vInit(tsDBG_FunctionTbl ****psFunctionTbl*);**

Description

This function is used to initialise the Debug module.

Note: If a JN51xx UART is to be used as the debug output interface, **DBG_vUartInit()** must be called instead. Thus, **DBG_vInit()** will not be needed by most users, since a UART will normally be used for debug output.

The function can be used during a cold start or a warm start (with memory held). Its parameter accepts a structure containing pointers to four user-defined callback functions concerned with the output interface:

```
typedef struct
  {
   void (*prInitHardwareCb)(void);
   void (*prPutchCb)       (char c);
   void (*prFlushCb)       (void);
   void (*prFailedAssertCb)(void);
  } tsDBG_FunctionTbl;
```

The callback functions pointed to by this structure are as follows:

***prInitHardwareCb**	Points to function which re-initialises the interface after a warm start, e.g. when JN51xx device wakes from sleep
***prPutchCb**	Points to function used by **DBG_vPrintf()** to output a single character to the interface
***prFlushCb**	Points to function used by **DBG_vPrintf()** to flush the interface buffer to allow buffered output characters to be displayed. If the output is unbuffered, this function should do nothing or wait for the last character output using the **putch()** function to be made available. Note that the function should not append a newline character, as this should be handled by the formatting string passed to **DBG_vPrintf()**
***prAssertFailedCb**	Points to function which is called when **DBG_vAssert()** fails. The function should stop execution and may reset the device

Parameters

***psFunctionTbl**	Pointer to structure containing list of callback functions.

Returns

None

DBG_vUartInit

```
void DBG_vUartInit(DBG_teUart eUart,
                   DBG_teUartBaudRate eBaudRate);
```

Description

This function is used to initialise the Debug module when one of the JN51xx on-chip UARTs is to be used as the output interface. In this case, this function should be called instead of **DBG_vInit()**. This will be the case for most users, as a UART will normally be used for debug output.

The function can be used during a cold start or a warm start (with memory held). It is necessary to specify the UART (0 or 1) and the required baud rate.

Note that the callback functions required by **DBG_vInit()** are not needed for **DBG_vUartInit()**, since they are pre-defined by NXP for the on-chip UARTs.

Parameters

eUart	UART to use as output interface, one of: DBG_E_UART_0 (UART0) DBG_E_UART_1 (UART1)
eBaudRate	Baud rate of UART, one of: DBG_E_UART_BAUD_RATE_4800 (4800 bps) DBG_E_UART_BAUD_RATE_9600 (9600 bps) DBG_E_UART_BAUD_RATE_19200 (19200 bps) DBG_E_UART_BAUD_RATE_38400 (38400 bps) DBG_E_UART_BAUD_RATE_76800 (76800 bps) DBG_E_UART_BAUD_RATE_115200 (115200 bps)

Returns

None

DBG_vPrintf

```
void DBG_vPrintf(bool_t bStreamEnabled,
                 const char *pcFormat, ...);
```

Description

This function is an adapted **printf()** function, allowing a formatted string to be output (e.g. via the UART) for display.

The function contains a parameter which allows the output of the string to be enabled or disabled - the value of this Boolean parameter must be a literal. If disabled, the compiler will optimise out this function, but its parameters will still be evaluated.

The supported output formats are as follows:

Format Specifier	Purpose
Flags	
-	Left align
0	Pad with zeroes
+	Sign with plus
‘ ‘ (space)	Sign with space
Width	
<integer>	Field width
Length	
l	Long
ll	Long long
h	Short
Type	
i	Signed integer
d	Signed integer
u	Unsigned integer
x	Unsigned integer as hexadecimal
p	Pointer
c	Character
s	String
Escape sequence	
\n	Newline/carriage return

Parameters

bStreamEnabled	Boolean which determines whether string will be output: TRUE: Output string FALSE: Do not output string (compile out function)
***pcFormat*	Pointer to printf-style formatting string
...	For supported output formats, see above table

Returns

None

DBG_vAssert

```
void DBG_vAssert(bool_t bStreamEnabled,
                 bool_t bAssertion);
```

Description

This function is an adapted **assert()** function, allowing a Boolean condition to be tested.

The function contains a parameter which allows the test to be enabled or disabled - the value of this Boolean parameter must be a literal. If disabled, the compiler will optimise out this function.

The Boolean condition to be tested is specified as a parameter:

- If the condition is TRUE, program execution continues.
- If the condition is FALSE, an error message is output and execution is passed to a callback function, which stops execution. This callback function is specified when **DGB_vInit()** is called for a cold start.

Parameters

bStreamEnabled	Boolean which determines whether test will be performed: TRUE: Perform test FALSE: Do not perform test
bAssertion	Boolean expression to be tested

Returns

None

DBG_vDumpStack

```
void DBG_vDumpStack(void);
```

Description

This function outputs the contents of the CPU stack (e.g. via the UART) for display.

Parameters

None

Returns

None

DBG_vFlush

```
void DBG_vFlush(void);
```

Description

This function flushes buffered characters from the JN51xx device to the display device. If the JN51xx UART is used for debug, this function flushes the UART buffer.

Parameters

None

Returns

None

DBG_iGetChar

```
int DBG_iGetChar(void);
```

Description

This function can be used to obtain a character from an input device (such as a serial terminal connected to the JN51xx UART).

Parameters

None

Returns

ASCII value of obtained character, or -1 if no character available

10. JCU Structures

This chapter describes the structures (including enumerations) used by the JCU modules:

- PDM structures are detailed in Section 10.1
- PWRM structures are detailed in Section 10.2
- DBG structures are detailed in Section 10.3

10.1 PDM Structures

10.1.1 PDM_tpfvSystemEventCallback

This type defines the callback function that receives PDM events.

```
typedef void (*PDM_tpfvSystemEventCallback) (
    uint32                          u32eventNumber,
    PDM_eSystemEventCode            eSystemEventCode);
```

where:

- `u32eventNumber` gives further information about the event depending on the event code, as detailed in Section 10.1.3
- `eSystemEventCode` identifies the type of event that triggered the callback.

10.1.2 tsReg128

This is a constant structure which contains a 128-bit encryption key used by the PDM module - the key is passed into the module via the **PDM_vInit()** function.

```
typedef struct
{
    uint32 u32register0;
    uint32 u32register1;
    uint32 u32register2;
    uint32 u32register3;
} tsReg128;
```

In the above structure, `u32register0` contains the 32 least signifacant bits and `u32register3` contains the 32 most significant bits of the key.

10.1.3 PDM_eSystemEventCode

This structure contains enumerations for the events generated by the PDM library.

```
typedef enum
{
  E_PDM_SYSTEM_EVENT_WEAR_COUNT_TRIGGER_VALUE_REACHED=0,
  E_PDM_SYSTEM_EVENT_SAVE_FAILED,
  E_PDM_SYSTEM_EVENT_PDM_NOT_ENOUGH_SPACE,
  E_PDM_SYSTEM_EVENT_LARGEST_RECORD_FULL_SAVE_NO_LONGER_POSSIBLE,
  E_PDM_SYSTEM_EVENT_SEGMENT_DATA_CHECKSUM_FAIL,
  // Debug event codes
  E_PDM_SYSTEM_EVENT_EEPROM_SEGMENT_HEADER_REPAIRED,
  E_PDM_SYSTEM_EVENT_SYSTEM_INTERNAL_BUFFER_WEAR_COUNT_SWAP,
  E_PDM_SYSTEM_EVENT_SYSTEM_DUPLICATE_FILE_SEGMENT_DETECTED,
  E_PDM_SYSTEM_EVENT_SYSTEM_ERROR,
} PDM_eSystemEventCode;
```

The events are outlined in Table 1 below.

Event Enumeration	Description
E_PDM_SYSTEM_EVENT_WEAR_ COUNT_TRIGGER_VALUE_REACHED	An EEPROM segment has reached a set Wear Count (set by the user or left at the manufacturer stated maximum value). `u32EventNumber` carries the EEPROM segment number.
E_PDM_SYSTEM_EVENT_SAVE_ FAILED	A save has failed. `u32eventNumber` contains the `u16IdValue` of the record that failed to save. This is a fatal error as the stack records may be inconsistent. Test software should log this error and halt. Production software may need to perform a factory reset.
E_PDM_SYSTEM_EVENT_PDM_NOT_ ENOUGH_SPACE	There is not enough space to hold all the PDM records. `u32eventNumber` contains the `u16IdValue` of the record that was being processed. This is a fatal error as the stack records may be inconsistent. Test software should log this error and halt. Production software may need to perform a factory reset.
E_PDM_SYSTEM_EVENT_LARGEST_ RECORD_FULL_SAVE_NO_LONGER_ POSSIBLE	The EEPROM occupancy is such that the largest record in the PDM can no longer be fully saved. `u32EventNumber` carries the `u16IdValue` of the record that was being processed.
E_PDM_SYSTEM_EVENT_SEGMENT_ DATA_CHECKSUM_FAIL	The calculated checksum for the data in an EEPROM segment does not match the stored checksum value. `u32EventNumber` carries the number of the segment.
E_PDM_SYSTEM_EVENT_EEPROM_ SEGMENT_HEADER_REPAIRED	This code can be ignored by the application software and only needs to be logged if requested by NXP Technical Support.

Table 1: PDM Event Codes (EEPROM)

Event Enumeration	Description
E_PDM_SYSTEM_EVENT_SYSTEM_INTERNAL_BUFFER_WEAR_COUNT_SWAP	This code can be ignored by the application software and only needs to be logged if requested by NXP Technical Support.
E_PDM_SYSTEM_EVENT_SYSTEM_DUPLICATE_FILE_SEGMENT_DETECTED	This code can be ignored by the application software and only needs to be logged if requested by NXP Technical Support.
E_PDM_SYSTEM_EVENT_SYSTEM_ERROR	This code can be ignored by the application software and only needs to be logged if requested by NXP Technical Support.

Table 1: PDM Event Codes (EEPROM)

10.1.4 PDM_teStatus

This structure contains enumerations for the status codes generated by the PDM.

```
typedef enum
{
    PDM_E_STATUS_OK,
    PDM_E_STATUS_INVLD_PARAM,
    // EEPROM based PDM codes
    PDM_E_STATUS_PDM_FULL,
    PDM_E_STATUS_NOT_SAVED,
    PDM_E_STATUS_RECOVERED,
    PDM_E_STATUS_PDM_RECOVERED_NOT_SAVED,
    PDM_E_STATUS_USER_BUFFER_SIZE,
    PDM_E_STATUS_BITMAP_SATURATED_NO_INCREMENT,
    PDM_E_STATUS_BITMAP_SATURATED_OK,
    PDM_E_STATUS_IMAGE_BITMAP_COMPLETE,
    PDM_E_STATUS_IMAGE_BITMAP_INCOMPLETE,
    PDM_E_STATUS_INTERNAL_ERROR
} PDM_teStatus;
```

The status codes are described in Table 2 below.

Event Enumeration	Description
PDM_E_STATUS_OK	The function completed without error.
PDM_E_STATUS_INVLD_PARAM	An invalid parameter value was supplied.
PDM_E_STATUS_PDM_FULL	There is no available EEPROM space for PDM.
PDM_E_STATUS_NOT_SAVED	A PDM save to EEPROM failed.
PDM_E_STATUS_RECOVERED	The record was recovered from a previous save to NVM.
PDM_E_STATUS_PDM_RECOVERED_NOT_SAVED	The record was not recovered from a previous save to NVM.
PDM_E_STATUS_USER_BUFFER_SIZE	Not used.
PDM_E_STATUS_BITMAP_SATURATED_NO_INCREMENT	Counter increment not made because the EEPROM segment is saturated.
PDM_E_STATUS_BITMAP_SATURATED_OK	Counter increment made but the EEPROM segment is now saturated.
PDM_E_STATUS_IMAGE_BITMAP_COMPLETE	For internal use.
PDM_E_STATUS_IMAGE_BITMAP_INCOMPLETE	For internal use.
PDM_E_STATUS_INTERNAL_ERROR	An unspecified internal PDM error has occurred.

Table 2: PDM Status Codes

10.1.5 PDM_tsHwFncTable

This structure is used in the function **PDM_vInit()** to specify a set of user-defined functions used to interact with a custom NVM device.

```
typedef struct
{
    /* This function is called after a cold or warm start */
    void (*prInitHwCb)(void);

    /* This function is called to erase the given sector */
    void (*prEraseCb) (uint8 u8Sector);

    /*This function is called to write data to an address
     * within a given sector. Address zero is the start of the
     * given sector */
    void (*prWriteCb) (uint8 u8Sector,
                       uint16 u16Addr,
                       uint16 u16Len,
                       uint8 *pu8Data);

    /* This function is called to read data from an address
     * within a given sector. Address zero is the start of the
     * given sector */
    void (*prReadCb)  (uint8 u8Sector,
                       uint16 u16Addr,
                       uint16 u16Len,
                       uint8 *pu8Data);
} PDM_tsHwFncTable;
```

10.2 PWRM Structures

10.2.1 PWRM_teSleepMode

This structure contains the enumerations used to set the power mode of the JN51xx device during sleep.

```
typedef enum
{
    PWRM_E_SLEEP_OSCON_RAMON,    /*32-kHz Osc on and RAM on*/
    PWRM_E_SLEEP_OSCON_RAMOFF,   /*32-kHz Osc on and RAM off*/
    PWRM_E_SLEEP_OSCOFF_RAMON,   /*32-kHz Osc off and RAM on*/
    PWRM_E_SLEEP_OSCOFF_RAMOFF, /*32-kHz Osc off and RAM off*/
    PWRM_E_SLEEP_DEEP,           /*Deep Sleep*/
} PWRM_teSleepMode;
```

10.3 DBG Structures

10.3.1 DBG_tsFunctionTbl

This structure contains callback functions used by the Debug (DBG) module to interact with the output interface.

```
typedef struct
   {
    void (*prInitHardwareCb)(void);
    void (*prPutchCb)       (char c);
    void (*prFlushCb)       (void);
    void (*prFailedAssertCb)(void);
   } DBG_tsFunctionTbl;
```

For details of the callback functions, refer to the description of DBG_vInit on page 98.

Revision History

Version	Date	Comments
1.0	11-Mar-2016	First release
1.1	6-July-2016	Updated for the JN517x devices

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