AVR2052: BitCloud Quick Start Guide

8-bit AVR® Microcontrollers

Application Note

Features

- **Introduces BitCloud Software Development Kit (SDK)**
- **Introduces WSNDemo application**

1 Introduction

This document is intended for engineers and software developers evaluating BitCloud ZigBee® PRO stack.

BitCloud SDK and the supported kits serve as the perfect vehicle to evaluate the performance and features of Atmel microcontrollers and radio transceivers as devices in a low power, ZigBee-compliant wireless sensor network. The SDK provides a complete software and documentation toolkit for prototyping, developing and debugging custom applications on top of BitCloud's application programming interface (API) as well as easily demonstrating ZigBee technology in action.

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[28] SAM3S-EK Development Board User Guide. http://www.atmel.com/dyn/resources/prod_documents/doc11031.pdf

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3 Overview

BitCloud is a full-featured, professional grade embedded software ZigBee stack from Atmel®. The stack provides a software development platform for reliable, scalable, and secure wireless applications running on Atmel microcontrollers and radio transceivers. BitCloud is designed to support a broad ecosystem of user-designed applications addressing diverse requirements while enabling a full spectrum of software customization.

The following hardware platforms are supported by BitCloud SDK.

Table 3-1. Supported hardware platforms

Name in This Document	Platform (MCU + RF)	Supported Modules	Supported External Flash for OTAU	Supported Evaluation Kit	SDK Package
ATAVRRZRAVEN	AT90USB1287 + AT86RF230 ATmega1284P + ATmega3290P + AT86RF230	N/A	N/A	ATAVRRZRAVEN (consists of ATAVRRZUSBSTICK and ATAVRRAVEN devices)	BitCloud for ATAVRRZRAVEN
ZigBit	ATmega1281 + AT86RF230	ATZB-24-B0 ATZB-24-A2 ATZB-A24-UFL ATZB-900-B0	AT25F2048, AT45DB041	N/A	BitCloud for ZIGBIT
megaRF	ATmega128RFA1	N/A	AT45DB041 (only 264 byte pages)	α-package and ATmega128RFA1-EK1 card hosted on STK600	BitCloud for MEGARF
XMEGA	ATxmega256A3 (D3)+ AT86RF231 or ATxmega256A3(D3) + AT86RF212 or ATxmega256A3(D3) + AT86RF230	N/A	AT45DB041 (only 264 byte pages)	ATxmega card hosted on STK600 and RZ600 radio boards	BitCloud for XMEGA

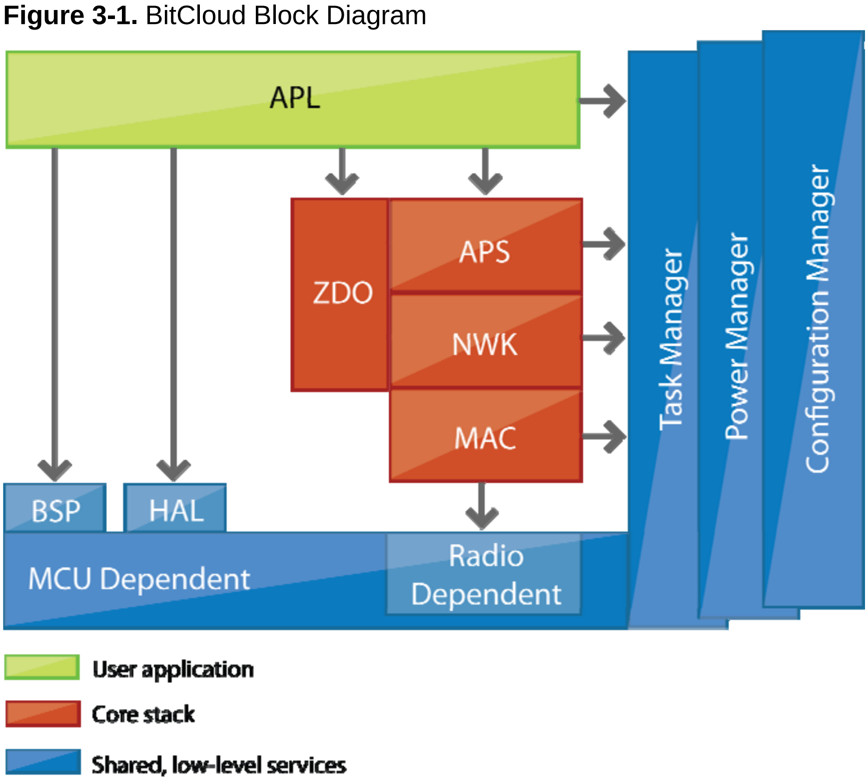
Name in This Document	Platform (MCU + RF)	Supported Modules	Supported External Flash for OTAU	Supported Evaluation Kit	SDK Package
UC3	AT32UC3A0512 + AT86RF231	N/A	N/A	EVK1105	BitCloud for 32-bit AVR UC3
SAM3S	ATSAM3S4C + AT86RF231 or ATSAM3S4C + AT86RF230 or ATSAM3S4C + AT86RF212	N/A	N/A	SAM3S-EK and RZ600 radio boards	BitCloud for SAM3S-EK
SAM7X	AT91SAM7X256 + AT86RF231 or AT91SAM7X256 + AT86RF230 or AT91SAM7X256 + AT86RF212	N/A	N/A	AT91SAM7X-EK and RZ600 radio boards	BitCloud for SAM7X-EK

Please note that this document describes the use of BitCloud with the specific modules and evaluation kits listed in the table above. Operation of BitCloud on supported MCU/RF combinations realized in a custom hardware application is outside the scope of this document.

BitCloud stack is fully compliant with ZigBee PRO and ZigBee standards for wireless sensing and control. It provides an augmented set of APIs which, while maintaining full compliance with the standard, offer extended functionality designed with developer's convenience and ease-of-use in mind.

The main structure of the BitCloud stack is presented in Figure 3-1.

Figure 3-1. BitCloud Block Diagram



The topmost of the core stack layers, APS, provides the highest level of networking-related API visible to the application. ZDO provides a set of fully compliant ZigBee Device Object API which enable main network management functionality (e.g. start, reset, formation, join). It also defines ZigBee Device Profile types, device and service discovery commands implemented by the stack.

The general guidelines to developing applications with BitCloud API are presented in [2]. The SDK also includes WSN Monitor PC application in binary format and WSNDemo embedded application available in binary format and source code.

The source code for WSNDemo application can be modified and extended, making it possible to develop WSN applications for a variety of application scenarios. WSN Monitor and WSNDemo applications are described in detail in Section 5.

For ZigBit, ATAVRRZRAVEN and SAM7X platforms, the SDK also includes other reference applications as described in Section 6.2.1.

4 Getting Started

This chapter describes how to quickly get BitCloud running on the selected hardware platform. BitCloud SDK is available for several platforms as described in Section 2, so before proceeding, select the SDK version that matches your target platform.

The majority of instructions for setting up BitCloud stack and applications depend on specific platform and evaluation kit. To get started, proceed to the platform-specific sections listed below.

Table 4-1. Hardware-Specific Getting Started Sections

For Platform	Refer to Section
ATAVRRZRAVEN	8.1
ZigBit	9.1
megaRF	10.1
UC3	11.1
XMEGA	12.1
SAM7X	13.1
SAM3S	14.1

After completing the installation, try running WSNDemo application by programming the devices with ready-to-use images as described in Section 0.

Finally, Section 5.5 describes how to get started creating new or modifying existing applications based on BitCloud C API.

5 WSNDemo Application

5.1 Overview

The network and radio frequency performance of the hardware components is demonstrated with WSNDemo application which is based on BitCloud API. This application consists of the embedded firmware, which supports functions for coordinator, router and end device, and the GUI visualization application, WSN Monitor, which is run on a PC. In WSNDemo, the nodes communicate based on a proprietary messaging protocol.

With WSNDemo application installed, the devices are organized into a set of nodes forming a ZigBee PRO network.

In case of ZigBit development boards, end devices and routers and the coordinator read the sensor data from on-board light and temperature sensors, and forward collected data to WSN Monitor application for visualization. On ATAVRRZRAVEN, XMEGA, SAM7X, SAM3S, megaRF and UC3 platforms, zero values are sent to the network coordinator to emulate sensor data and demonstrate data transmission.

End devices follow a duty cycle (i.e. microcontroller and radio transceiver are put to sleep periodically) and wake up to transmit data to the coordinator. Using the serial connection, the coordinator transmits the received packets, along with its own sensor data (or emulated sensor data), to WSNMonitor application. Those transmitted values are displayed on WSNMonitor panes as temperature, light and battery level measurements.

WSN Monitor also visualizes network topology by drawing a tree of nodes which have joined the network. For each of the nodes, the parameters like the node's address, its node sensor information and link quality data are displayed.

Measured in dBm, *RSSI* indicates a link's current condition. The RSSI resolution is 3 dBm. *LQI* is another numeric parameter defined within the 0 to 255 range to measure the link quality. Larger values mean a better link while values close to zero indicate a poor connection.

In WSNDemo the number of routers and end devices is limited only by the network parameter settings described in Section 6.2.1. However, for ATAVRRZRAVEN kit additional restrictions apply. These are outlined in Table 5-1.

Table 5-1. Allowed board role / device type combinations for WSNDemo on ATAVRRZRAVEN

Device Type	Allowed Board Role	Comments
Coordinator	RZUSBSTICK	Coordinator needs USB interface to send data to PC-side WSNMonitor application
Router	AVRRAVEN or RZUSBSTICK	
End-Node	AVRRAVEN	End-nodes also demonstrate sleep capabilities (MCU and RF only)

In reference to WSNDemo application, Section 5.3 describes how to setup and use the boards. The user interface is described in Section 5.5.

The application is delivered with source code which demonstrates how to develop a wireless network application using BitCloud API and provides a number of useful programming templates for common application tasks. Development of custom applications is described in Section 5.5.

5.2 Programming the Boards

As a first step, WSNDemo images should be loaded onto the boards. The locations of WSNDemo image files are platform specific and are provided in sections specified in Table 4-1.

The programming instructions and the sets of pre-built application images provided with the SDK also depend on the target platform. The table below provides references to the sections that describe how to program each target platform and evaluation kit.

Table 5-2. Platform-Specific Programming Sections

For Platform	Refer to Section
ATAVRRZRAVEN	8.2
ZigBit / ZigBit Amp / ZigBit 900	9.2
megaRF	10.2
UC3	11.2
XMEGA	12.2
SAM7X	13.2
SAM3S	14.2

Running any ZigBee or ZigBee PRO application, WSNDemo included, requires that every device in the network has a 64-bit unique *MAC address*. See the appropriate sections in Table 5-2 for how MAC addresses are assigned for each type of supported boards. In order to make initial setup easier, there are a number of pre-compiled images provided with the SDK that can be used right away without any modification.

ZigBit and ATAVRRZRAVEN platforms do not require manual assignment of MAC addresses as the evaluation boards are equipped with a dedicated unique ID chip or

EEPROM, which BitCloud stack uses automatically on start up. Also, note that the default images are configured to use a particular *extended PAN ID* and *channel mask*. To change those parameters the user has to modify the `Configuration` file and rebuild the application as described in Section 6.2.1. All and all, special care must be taken by the user when configuring an application so that each compiled image contains a unique MAC address and all images share the same extended PAN ID and channel mask.

5.3 Running WSNDemo

Each target platform requires its own set of instruction for getting WSN Demo application to run. Table below provides references to the sections with platform-specific instructions.

Table 5-3. Platform-Specific WSNDemo Sections

For Platform	Refer to Section
ATAVRRZRAVEN	8.4
ZigBit	0
megaRF	10.4
UC3	11.4
XMEGA	12.4
SAM7X	13.4
SAM3S	14.4

5.4 Network Startup

The coordinator organizes the wireless network automatically. Upon starting, every node informs the network on its role.

When the coordinator is powered on it switches to an active state, even though no child node is present. This is normal, and it indicates that the coordinator is ready and child nodes can join the network with the coordinator's extended PAN ID. By default, the coordinator uses extended PAN ID 0xAAAAAAAAAAAAAAAA, which is recognized by all routers. A *short PAN ID* is chosen at random. The extended PAN ID can be modified by the user through the application `Configuration` file as described in Section 6.2.1.

Note: If the coordinator is absent or has not been turned on, the routers and end devices will remain in the network search mode. In this mode, routers scan the channels specified in the channel mask in search of a network with the specified extended PAN ID.

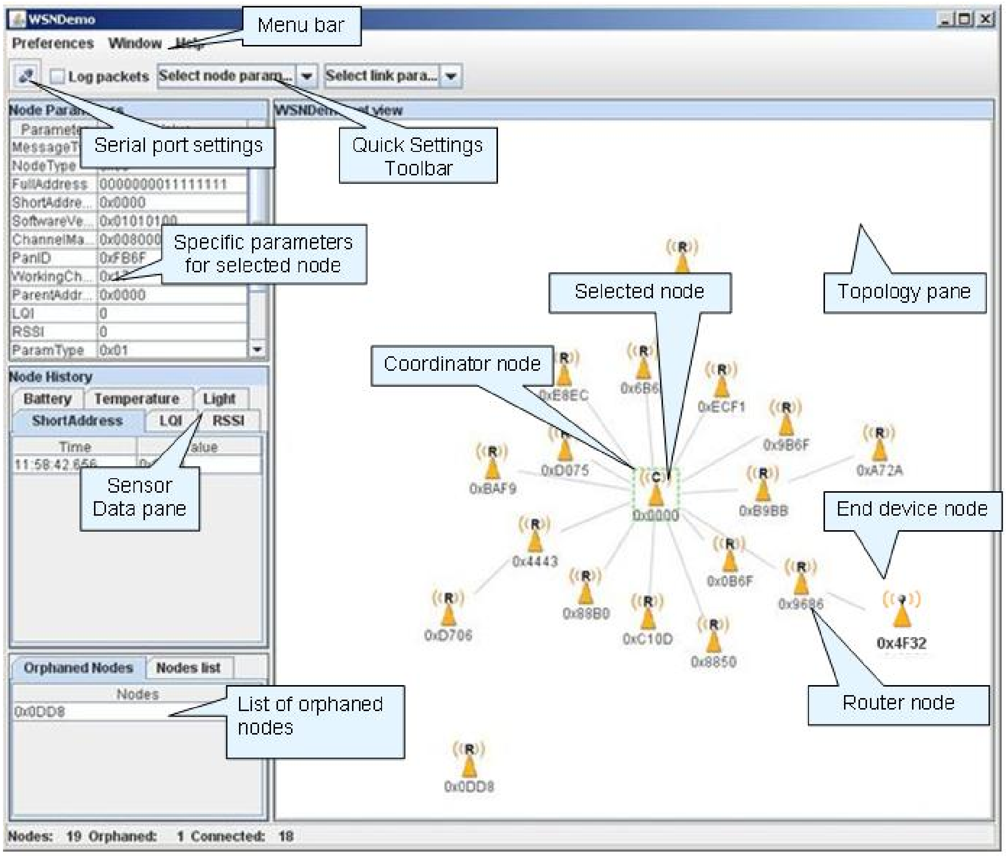
By default, the channel mask for all application images provided with SDK contains a single channel. In rare cases, if the frequency corresponding to the radio channel is busy, the coordinator node may stay in the network search mode. If this happens, it may be necessary to change the application's channel mask to select another channel by changing the application's `Configuration` file, and recompiling the application as described in Section 6.2.1.

Network health can be monitored by looking at the individual node's LED state (LED states are platform specific and are described in platform-specific sections noted in table above) or through WSN Monitor application described in the next section.

5.5 WSN Monitor

WSN Monitor is a PC counterpart for WSNDemo embedded application, and it can be used to display ZigBee network topology and other information about a wireless sensor network. A typical WSN Monitor screen is shown in the figure below. It contains *topology pane*, *sensor data pane*, *node data pane* and application toolbars.

Figure 5-1. WSN Monitor GUI



Topology pane displays the network topology in real time, which helps the user monitor the formation and dynamic changes in the network while the nodes join, send data or leave. The network topology is constructed on the basis of next hop information for each of the nodes, and each link is also tipped with RSSI and LQI values. Each of the nodes displayed is depicted by an icon with the node's address or name below and sensor readings to the right of the icon if required by settings.

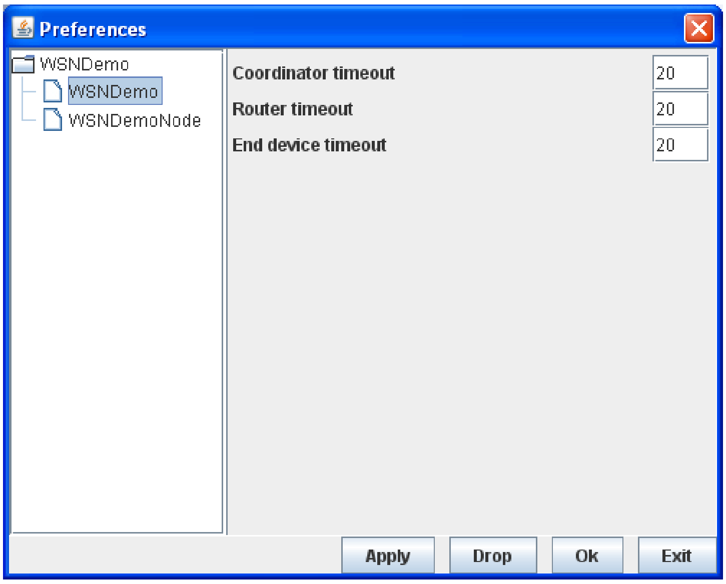
Sensor data pane displays data coming from onboard sensors of the selected node (see Section 5.5.2). It is presented in graph and table form. Other parameters can be observed for each node in table form. Node data pane includes a *sensor selection combo-box* used to switch between sensor types.

By default in topology pane nodes are labeled with their short addresses. However by a double click another title can be assigned to any desired node. If "Cancel" is pressed in opened window short address is set back as node's title.

5.5.1 Node Timeouts

The `Window/Preferences` menu of WSN Monitor contains a number of parameters used to control application behavior. Timeouts are used to tune visualization of coordinator, routers and end devices as the nodes disappear from the network each time a connection is lost, power is down, or a reset has occurred. A node timeout corresponds to the time the WSN Monitor application waits for a packet from a particular node before assuming that a node is no longer part of the network. Note that this value does not correspond to the frequency with which data is transmitted by each type of device. To get smooth topology visualization, setting timeouts to 20 sec is recommended for coordinator and router and 30 sec is recommended for end device. Assuming default application configuration, these timeouts cover 3 periods between sending a packet so at least 3 packets would need to be lost before a node is removed from WSN Monitor's Topology Pane.

Figure 5-2. WSNMonitor Preferences menu



5.5.2 Sensor Data Visualization

Each of the boards sends temperature/light/battery sensors readings (or emulated values) to the coordinator, which in turn sends it to the PC. WSN Monitor displays the readings from onboard sensors next to a node icon inside Topology Pane (see Section 5.5). For this corresponding option shall be selected in the node/link parameters from the Quick Settings Toolbar.

The user can select any node in Topology Pane to monitor the node's activity and see the node data in three different forms:

- Text table
- Chart
- The onboard sensor's data displayed next to each node in topology pane. These values are also tipped with arrows indicating whether the value increased or decreased in relation to the previous sample.

Note: A given node is selected when clicked on and a dashed frame is drawn around it.

The same values are shown on Sensor Data Pane, so the user can observe how the values change over a period of time.

Sensor Data Pane includes a Sensor Selection combo-box. Use the button on the Sensor Control Toolbar to display the desired types of sensor data.

5.5.3 Over-the-Air Upgrade

OTA upgrade can be executed on supported HW platforms by loading special version of WSNDemo application with OTA support. Such demonstration also requires an additional in-network device to perform the role of the upgrade client, i.e. the devices that sends new firmware images to other devices on the network.

The details of running OTAU in WSNDemo differ for each platform. Please refer to an appropriate section listed in the table below for the platform-specific instructions.

Table 5-4. Platform-Specific WSNDemoOTA settings

For Platform	Refer to Section
ZigBit	9.3.4
megaRF	10.4.3
XMEGA	12.4.3

After WSNDemoOTA device(s) are configured, programmed and joined to the network, follow step-by-step instructions below to execute an over-the-air upgrade:

1. Connect Runner device to PC
2. Start OTAU Bootloader PC utility (from Microsoft® Windows® Start Menu, select `Atmel -> Bootloader -> Bootloader`):
    a. On the `OTAU` tab select network parameters as shown in Figure 5-3 below.
    b. Specify `Connection` settings to match the port where Runner device is connected.
    c. Click `Start` button
    d. The utility will automatically populate the list of devices which support OTA functionality (i.e. applications that include OTA cluster). By default only devices programmed with WSNDemo with OTA support should be shown in the list as seen in Figure 5-4.
3. Start Image Converter PC utility (from Windows Start Menu, select `Atmel -> Bootloader -> Converter`):
    a. Select `*.srec` image(s) you wish to upload to a remove OTA-capable device over the air
    b. Fill in image metadata information in fields below and click `Convert`.
4. Return to OTAU Bootloader PC utility:
    a. Click on Upload button next to device information (see).
    b. In Open File dialog, select `*.zigbee` file which was converted in step 5.
    c. Click OK, and the upload process should commence. It usually takes 5-10 minutes to upload a single image to a router device and up to 2 hours to upload a single image to a sleeping end device.
    d. Once the image is uploaded the device will reset and run the uploaded firmware.

Figure 5-3. OTAU Bootloader main screen

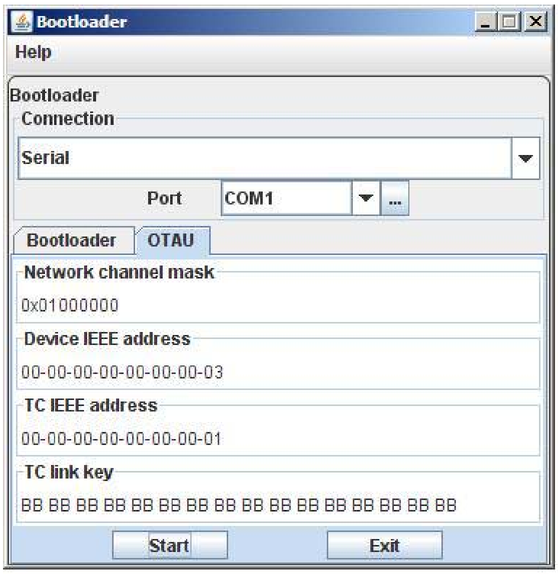
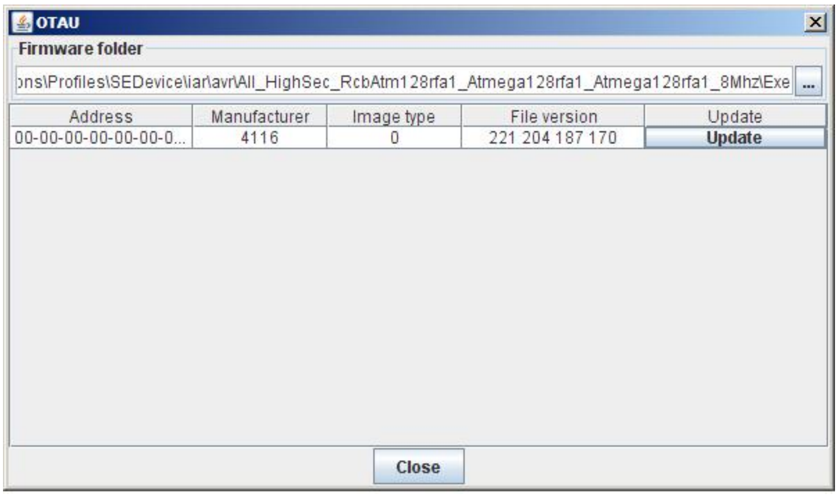


Figure 5-4. OTAU Bootloader device screen



6 Developing Custom Applications with BitCloud API

6.1 API Overview

The BitCloud internal architecture follows IEEE 802.15.4 and ZigBee-defined convention for splitting the networking stack into layers. Besides the core stack containing the protocol implementation, BitCloud contains additional layers implementing shared services (e.g. task manager, configuration manager, and power manager) and hardware abstractions (e.g. hardware abstraction layer (HAL) and board support package (BSP)). The APIs contributed by these layers are outside the scope of core stack functionality. However, these essential additions to BitCloud API significantly reduce application complexity and simplify the development effort. BitCloud Stack Documentation [1] provides detailed information on the stack's C API and its use.

The topmost of the core stack layers, APS, provides the highest level of networking-related APIs visible to the application. ZDO provides a set of fully compliant ZigBee Device Object APIs which enable main network management functionality (e.g. start, reset, formation, join). ZDO also defines ZigBee Device Profile types, device and service discovery commands implemented by the stack.

There are three service "planes" including: task manager, configuration manager, and power manager. These services are available to the user application, and may also be utilized by lower stack layers. Task manager is the stack scheduler which all multiple internal stack components and the user application to run on the same microcontroller. The task manager utilizes a proprietary priority queue-based algorithm specifically tuned for multi-layer stack environment and demands of time-critical network protocols. Power management routines are responsible for gracefully shutting down all stack components and saving system state when preparing to sleep and restoring system state when waking up. Configuration manager is used by both the internal stack components and the user application alike to provide a common way to store and retrieve network parameters like Extended PAN ID and channel mask.

The Hardware Abstraction Layer (HAL) includes a complete set of APIs for using on-module hardware resources (e.g. EEPROM, app, sleep, and watchdog timers) as well as the reference drivers for rapid design-in and smooth integration with a range of external peripherals (e.g. IRQ, TWI, SPI, UART, 1-wire), where hardware interface is supported by the platform. Board support package (BSP) includes a complete set of drivers for managing standard peripherals (e.g. sensors, UID chip, sliders, and buttons) placed on development boards such as those provided with ZigBit, ZigBit Amp and ZigBit 900 evaluation kits.

Please refer to [1] and [2] for a more detailed description of the BitCloud API and its features.

6.2 Development Tools

A development tool chain consists of:

1. An integrated development environment (e.g. AVR Studio or IAR Embedded Workbench) where sample applications may be modified, compiled and debugged,
2. A corresponding compiler tool chain (e.g. WinAVR, IAR™ or YAGARTO) which provides everything necessary to compile application source code into binary images, and
3. A programming device (e.g. JTAG), which may be used to program and debug the application on a target platform.

IAR Embedded Workbench for Atmel AVR [13] can be used to develop and debug applications for AVR-based platforms including ZigBit, megaRF, ATAVRRZRAVEN and XMEGA. IAR Embedded Workbench for ARM and AVR32 can be used to develop and debug applications on ARM-based platforms and 32-bit AVR platforms, respectively. All IAR IDEs supports editing of application source code, compilation, linking object modules with libraries, and application debugging.

Atmel's AVR Studio [3] can be used to develop and debug applications for AVR-based platforms. AVR Studio is closely integrated with WinAVR – a Windows port of GNU compiler tool chain for the Atmel AVR microprocessors. More information about WinAVR and GNU compiler tools is available in [4] and [5].

Eclipse IDE [22] and/or IAR Embedded Workbench for ARM [21] may be used to develop and debug applications based on BitCloud API on SAM7X. Eclipse IDE can be integrated with YAGARTO compiler tool chain [23] to support seamless application programming and debugging on SAM7X all inside Eclipse IDE.

In AVR Studio, each application has a corresponding project file identified by the `.aps` extension. All the necessary information about a project is contained in the project file, which can be double-clicked to open the application's project in AVR Studio. Likewise, In IAR Embedded Workbench, each application has a corresponding `.eww` file which can be double-clicked to open the application's project. For detailed instructions on how to compile and debug applications using the supported tools, refer to Section 6.2.2.

Platform-specific sections which describe development tools installation and setup instructions are listed in Table 4-1.

6.2.1 Reference Applications

All BitCloud SDKs are supplied with WSNDemo reference application provided in source code. WSNDemo is presented in detail in Section 5. To better understand the application payload format between the network nodes and between the coordinator and the PC, the user can refer to Appendix 15 and Appendix 16.

For some platforms additional sample applications are available as indicated in the table below. The user is encouraged to browse reference applications source code as a reference for customer application being built. In many case, reference application source code can be used in the target application with only minor modifications.

Table 6-1. Reference Applications

Application	Brief Description	ATAVRRZRAVEN	ZigBit	megaRF	UC3	XMEGA	SAM7X	SAM3S
WSNDemo	Featured SDK application demonstrating network functionality of software and additional network visualization with WSN Monitor. See section 5.	X	X	X	X	X	X	X
Blink	Introduces the simplest application that uses timer and LEDs. When started, the application makes all the LEDs blink synchronously with a certain period.	X	X				X	
Lowpower	Show how to collect data from low-power, sleeping devices employing the simplest power management strategy.	X	X					

Application	Brief Description	ATAVRRZRAVEN	ZigBit	megaRF	UC3	XMEGA	SAM7X	SAM3S
Peer2peer	Shows how to organize the simplest peer-to-peer link. A simple buffering strategy is employed to avoid byte-by-byte data transfer.	X	X				X	
PingPong	Shows how process multiple simultaneous data transmissions. Each node is waiting for a wireless message, and then passes it to the next node.		X				X	
ThroughputTest	Measures wireless UART bandwith of ZigBit, ZigBit Amp and ZigBit 900 boards.	X	X				X	
ZDPDemo	Demonstrates ZDP requests to reveal properties of remote devices.						X	

For more details on sample applications available for a specific platform refer to [1].

Once the SDK is installed, the source code for the WSNDemo application can be found inside the "`<SDK-Root>\Applications\WSNDemo`" directory. For other sample applications (where available), the source code can be found in "`<SDK-Root>\Applications\<application-name>`" directories.

Network parameters and their default values are defined in `Configuration` file. However, when the application is compiled using IAR Embedded Workbench IDE, the network parameters are defined in "`iarConfiguration.h`" file located in "`iar/AVR`" subdirectory of the appropriate application directory. For WSN Demo application, this file is located in "`<SDK-Root>/Applications/WSNDemo/iar/AVR`". In all other cases, including compiling from the command line using IAR compiler, `Configuration` file will be used.

6.2.2 Supported Toolchains

The following development environment options are available for each of the supported platforms.

Table 6-2. Platform-Specific Compilation Options

For Platform	AVR Studio + WinAVR	Eclipse + YAGARTO	IAR Embedded Workbench
ATAVRRZRAVEN	X		X
ZigBit	X		X
megaRF	X		X
UC3			X
XMEGA	X		X

For Platform	AVR Studio + WinAVR	Eclipse + YAGARTO	IAR Embedded Workbench
SAM7X		X	X
SAM3S			X

In order to compile an application in each of the available development environments, the following steps should be taken:

6.2.2.1 AVR Studio + WinAVR

- *Command line:* Compile application by running `make` utility. Before running `make`, be sure that `Configuration` file has `COMPILER_TYPE` variable set to `GCC`.
- *IDE:* Open the `.aps` file from the appropriate directory with AVR Studio and execute “`Build/Rebuild All`” from the main menu.

Once the build process is complete, `.hex, .srec, .bin and .elf` application images will be generated.

6.2.2.2 Eclipse + YAGARTO

- *Command line:* Compile application by running `make` utility. Before running `make`, be sure that Configuration file has `COMPILER_TYPE` variable set to `GCC`.
- *IDE:*

1. In Eclipse framework create new C project of Makefile type with arbitrary name but location in application directory (e.g. “`<SDK-Root>\Applications\WSNDemo`” directory).
2. Configure project properties as follows:
    a. Select C/C++ Build, Discovery Options
    b. In the Compiler invocation command” section, browse to the compiler.(`C:\Program Files\yagarto\bin\arm-elf-gcc.exe`)
    c. Select C/C++ Build, Settings
    d. Check GNU Elf Parser
    e. Select GNU Elf Parser
    f. Browse to the addr2line and c++filt programs (`C:\Program Files\yagarto\bin\arm-elf-addr2line.exe`) (`C:\Program Files\yagarto\bin\arm-elf-c++filt.exe`)
    g. Apply and Click `Ok`

While building, the output of ‘make’ command will appear in the “Console” pane on the bottom of the window. Once the build process is complete `.hex, .srec, .bin and .elf` image files will be generated.

6.2.2.3 IAR Embedded Workbench

- *Command line:* Compile application by running `make` utility. Before running make, be sure that `Configuration` file has `COMPILER_TYPE` variable set to `IAR`. The `.hex`, `.srec, .bin and .elf` image files will then be generated.
- *IDE:* Open the `.eww` file in the “`iar/AVR`” for ZigBit, RZRAVEN or XMEGA platforms or “`iar/ARM`” for SAM7X and SAM3S subdirectory of the appropriate application directory (for WSN Demo `WSNDemo.eww` file from the “`<SDK-Root>\`

Applications\WSNDemo\iar\AVR" subdirectory) with IAR Embedded Workbench and execute "Rebuild All" item from the Project menu. By default the .a90 (for WSNDemo: WSNDemo.a90) file will be generated in the "iar/AVR/Debug/exe" subdirectory (for WSNDemo: in "./Applications/WSNDemo/iar/AVR/Debug/exe" directory) with format as specified in Linker Output Options of the IAR project.

6.3 Reserved Hardware Resources

Hardware resources provided by the supported hardware include microcontroller peripherals, buses, timers, IRQ lines, I/O registers, etc. Many of these interfaces have corresponding APIs in hardware abstraction layer (HAL) of the BitCloud stack. When building custom applications on top of the BitCloud API, the user is strongly encouraged to use the high-level APIs instead of the low-level register interfaces to ensure that the resource use does not overlap with that of the stack.

The hardware resources reserved for the internal use by the stack in BitCloud are listed in platform-specific sections specified in the table below. These resources must not be accessed by the application code. Please note that the lists of the reserved hardware resources differ for each device.

Table 6-3. Platform-Specific Reserved Resources

For Platform	Refer to Section
ATAVRRZRAVEN	8.5
ZigBit / ZigBit Amp / ZigBit 900	0
ATmega128RFA1	10.5
UC3	11.5
XMEGA	12.4.3
SAM7X	13.5
SAM3S	14.5

7 Basic Troubleshooting

In case of any operational problem with your setup, please check the following:

1. Check the power first, and make sure that all of your equipment is properly connected.
2. Verify that PC conforms to the minimum system requirements (see Section 4).
3. Verify that PC USB or UART interface is working and the correct drivers are installed (see Section 4).
4. Check hardware kit documentation, and if you have setup hardware according to specific kit instructions.. See Section 4 for specific hardware setup requirements.
5. For ATAVRRZRAVEN, check LCD indication of AVRRAVEN nodes to detect the cases when they are not responding or behaving unusually.
6. Make sure you have programmed the right images and set the correct Fuses values (see Section 0). Resetting the node may be required.

The table below represents some typical problems that you may encounter while working with the Development Kit and possible solutions.

Table 7-1. Typical problems and solutions

Problem	Solution
For ATAVRRZRAVEN: The AVRRAVEN board does not indicate its activity on LCD.	Make sure that WSNDemo image is loaded. The LCD controlling logic depends on the application, and may work differently for the images built by you.
WSN Monitor fails to start.	Make sure Java machine is properly installed on your PC. See Section 4.
No node is shown on the Topology Pane in the WSN Monitor	Check if the WSN Monitor uses the proper COM port and if not, change it and restart the program.
WSN Monitor shows NO DATA in the Sensor Data Graph Pane.	No node is selected. Select the required node by mouse-clicking on it.
Node titles displayed on the Topology Pane do not show node destinations.	The displayed titles do not necessarily relate to the node functions but they can be redefined by the user at any time. These names are stored in the node title file (see Section 5.5) along with MAC addresses mapped to the nodes.

8 Appendix A-1. ATAVRRZRAVEN Specifics

8.1 Getting Started

8.1.1 Required Hardware

Before installing and using the BitCloud SDK make sure that all necessary hardware is available for the kit you would like to use:

1. One ATAVRRZUSBSTICK
2. One or more ATAVRRAVEN boards
3. 100-mil to 5o mil JTAG adapter
4. JTAGICE mkII

8.1.2 Hardware Setup

1. Solder the JTAG headers onto the boards as described in [7].
2. Make sure that the boards have fresh batteries.

8.1.3 System Requirements

Before using the SDK, please ensure that the following system requirements are met by your PC and development environment.

Table 8-1. System requirements for ATAVRRZRAVEN

Parameter	Value	Note
CPU	Intel® Pentium III or higher, 800MHz	
RAM	128MB	
Free space on hard disk	50MB	
JTAG emulator	JTAGICE mkII emulator with cable	Required to upload and debug firmware onto the boards through JTAG (see Section 0).
Operating system	Windows 2000/XP	
IDE	AVR Studio 4.18 Service Pack 2 and WinAVR 20100110 (1) OR IAR Embedded Workbench AVR 5.50 (with IAR C/C++ Compiler for AVR 5.50.0.50277 (2))	Required to upload firmware images through JTAG (see Section 0), and to develop applications using API (see Section 6.2)
Java Virtual Machine	Java Runtime Environment (JRE) 5 Update 8, or later	Required to run WSNMonitor application

Notes: 1,2 Users are strongly encouraged to use specified versions of WinAVR and IAR C/C++ Compiler for AVR. Other versions are not supported and may not work.

8.1.4 Installing the SDK

Proceed with the following installation instructions:

1. Download the archive to your PC and unpack it into an empty folder. Make sure that path to this folder contains no blank spaces. As a result, the following SDK folders and files will be created with `<SDK-Root>` being the top level SDK folder.

Table 8-2. The SDK file structure

Directory/File	Description
`<SDK-Root>\Documentation`	Documentation on BitCloud software
`<SDK-Root>\Evaluation Tools\WSNDemo (Embedded)`	Ready-to-use image files for evaluating WSNDemo. Refer to section 8.3 0for the description of the images
`<SDK-Root>\Evaluation Tools\WSNDemo (WSN Monitor)\WSNMonitorSetup.exe`	WSN Monitor installer
`<SDK-Root>\Evaluation Tools\SerialNet`	Ready-to-use image file for SerialNet application. Firmware can be used on ATAVRRZUSBSTICK only. Refer to [10] for more information on SerialNet.
`<SDK-Root>\BitCloud\Components`	Header files for BitCloud Stack
`<SDK-Root>\BitCloud\Components \BSP\`	Source, header and library files for BitCloud BSP
<SDK-Root>\`BitCloud\Components\BSP\ RAVEN\AT3290P`	Source and header files for LCD controller firmware
`<SDK-Root>\BitCloud\lib`	Library files for BitCloud Stack
`<SDK-Root>\Applications`	Source files for sample applications.
`<SDK-Root>\Third Party Software\6119.inf`	USB to Serial Converter driver

2. Install desired IDE:
   a. For AVR Studio and WinAVR:
      i. Install AVR Studio [3], if not already installed on your PC.
      ii. Install WinAVR development suite [4], if not already installed on your PC. Be sure to install only the supported version of WinAVR as specified in Table 8-1.

   b. For IAR Embedded Workbench AVR:
      i. Install IAR Embedded Workbench for AVR [13], if not already installed on your PC.
      ii. In SDK directory "`./BitCloud/lib/`" make sure that in files "`Makerules_AtmlUsbDongle_At90usb1287_8Mhz_Iar`" and "`Makerules_Raven_Atmega1284_4Mhz_Iar`" the IAR_PATH variable points to the correct installation directory of IAR Embedded Workbench. Update, if needed.
      iii. Add a Windows® environment variable called IAR_AVR_HOME and set its value to the installation directory of IAR Embedded Workbench (for default installation it is "`C:\Program Files\IAR`

Systems\Embedded Workbench 5.4_0"). To do this go to Control Panel > System > Advanced > Environment Variables, click New below System variables list and enter Variable Name and Variable Value. This step is required if you plan to build embedded images using IAR Embedded Workbench from command line.

3. Install USB to Serial Converter driver. To install the driver, attach the RZUSBSTICK device to your PC and wait for Windows® to request a specific driver for the device. If the RZUSBSTICK already has an assigned driver, or Windows assigned driver to it automatically, go to Start -> Control -> Panel -> System -> Hardware -> Device Manager, double-click RZUSBSTICK device and select "Update Driver…". Choose the "Install from a list or specific location" option and point to 6119.inf provided with this SDK. Please refer to section 4.9.1 of [8] for further details and basic troubleshooting options.
4. Download and install Java Runtime Environment [12], if not already installed on your PC.

8.2 Programming the Boards

8.2.1 Setting Parameters

At startup the software assigns the 64-bit MAC address to the device as follows. If at compile time CS_UID parameter is set to 0 BitCloud attempts to load MAC address from an external EEPROM chip available on RZRAVEN and RZUSBSTICK boards. If there is no such UID then zero MAC address will be assigned to the device. Note that for proper operation all nodes in the network shall have unique MAC address values. Hence, if address cannot be obtained automatically from external source, separate firmware images shall be created for each device with unique CS_UID parameter specified in application configuration (see Section 156.2.1) every time an image is compiled.

8.2.2 Programming

Refer to AVR Studio [3] and IAR Embedded Workbench [13] documentation for the description of how the images can be programmed to the boards using JTAG.

Set the following options in the Fuses tab before uploading the image through JTAG. Note the values differ for different types of boards.

Table 8-3. Fuse bits setting for AT90USB1287 (RZUSBSTICK)

Option	Value
BODLEVEL	Brown-out detection at VCC=2.4 V
HWBE	Disabled
OCDEN	Disabled
JTAGEN	Enabled
SPIEN	Enabled
WDTON	Disabled
EESAVE	Disabled
BOOTSZ	Boot Flash size=4096 words start address=$F000
BOOTRST	Disabled
CKDIV8	Disabled

Option	Value
CKOUT	Disabled
SUT_CKSEL	Ext. Crystal Osc. 3.0-8.0 MHz; Start-up time: 16K CK + 65 ms
EXTENDED	0xFC
HIGH	0x99
LOW	0xFD

Table 8-4. Fuse bits setting for ATmega1284p (AVRRAVEN)

Option	Value
BODLEVEL	Brown-out detection at VCC=1.8V
OCDEN	Disabled
JTAGEN	Enabled
SPIEN	Enabled
WDTON	Disabled
EESAVE	Disabled
BOOTSZ	Boot Flash size=512 words start address=$FE00
BOOTRST	Disabled
CKDIV8	Enabled
CKOUT	Disabled
SUT_CKSEL	Int. RC Osc.; Start-up time: 6 CK + 65 ms
EXTENDED	0xFE
HIGH	0x9F
LOW	0x62

Table 8-5. Fuse bits setting for ATmega3290p (LCD on AVRRAVEN)

Option	Value
BODLEVEL	Brown-out detection at VCC=1.8V
RSTDISBL	Disabled
OCDEN	Disabled
JTAGEN	Enabled
SPIEN	Enabled
WDTON	Disabled
EESAVE	Disabled
BOOTSZ	Boot Flash size=512 words start address=$3E00
BOOTRST	Disabled
CKDIV8	Enabled
CKOUT	Disabled
SUT_CKSEL	Int. RC Osc.; Start-up time: 6 CK + 65 ms
EXTENDED	0xFD
HIGH	0x9D
LOW	0x62

For additional details, please refer to `“readme.html > RZRAVEN: RZRAVEN Firmware Documentation > Miscellaneous information > Programming the RZRAVEN Firmware with Programmer/Debugger”` section of [6].

8.3 Pre-Built Images

The SDK comes with ready-to-use binary images of WSNDemo application. There is a set of images for different device types:

1. `WSNDemoApp_USB_Coord.hex` – for RZUSBSTICK (AT90USB1287 controller) acting as Coordinator
2. `WSNDemoApp_USB_Router.hex` – for RZUSBSTICK (AT90USB1287 controller) acting as Router
3. `WSNDemoApp_Raven_Router.hex` – for AVRRAVEN (ATmega1284p microcontroller) acting as Router
4. `WSNDemoApp_Raven_EndDev.hex` – for AVRRAVEN (ATmega1284p microcontroller) acting as End Device
5. `Raven_3290P_LCD.hex` – for AVRRAVEN’s LCD controller (ATmega3290p)

And SerialNet application [10] for RZUSBSTICK:

6. `SerialNet_USB.hex`

In all ready-to-use binary images MAC address (`CS_UID`) is loaded automatically from a dedicated external EEPROM chip, ensuring that unique MAC addresses are assigned to all network nodes. Note that the default WSNDemo images are configured to use Extended PAN ID `0xAAAAAAAAAAAAAAAA` and channel mask with only channel `0x0F` enabled for operation.

8.4 Running WSNDemo

8.4.1 Starting WSNDemo

To start WSNDemo, do the following:

1. Setup the hardware as described in Section 8.1.2.
2. Install BitCloud SDK as described in Section 8.1.4.
3. Load precompiled WSNDemo firmware images to devices:
    a. On RZUSBSTICK (Coordinator): `WSNDemoApp_USB_Coord.hex`;
    b. On AVRRAVEN (Router): `WSNDemoApp_Raven_Router.hex` for ATmega1284p microcontroller and `Raven_3290P_LCD.hex` for ATmega3290p LCD controller (the board contains two JTAG headers – refer to [6]);
    c. On AVRRAVEN (End-Device): `WSNDemoApp_Raven_EndDev.hex` for ATmega1284p microcontroller and `Raven_3290P_LCD.hex` for ATmega3290p LCD controller (the board contains two JTAG headers – refer to [6]);
4. Plug in the coordinator USB stick into PC.
5. Run WSN Monitor (see Section 5.5).
6. Power on the rest of the nodes.

8.4.2 Monitoring WSNDemo Activity

Network activity can be monitored in two ways:

- Observing the LCD screens of AVRRAVEN devices and color LEDs of RZUSBSTICK devices (see meaning of LCD information and LEDs described in the tables below);
- Monitoring network information through the WSN Monitor installed on PC.

Table 8-6. LCD indication for AVRRAVEN boards used in WSNDemo

Node State	Visual Information on LCD Screen
Searching for network	“JOINING” string displayed; red LED blinking; “sun” symbol displayed
Joined to network	“ROUTER” or “ENDDEV” string displayed, depending on the node role; red LED is on; “sun” symbol displayed
+ receiving data	“RX” indicator visible (please note the limitations due to LCD refresh rate)
+ sending data	“TX” indicator visible (please note the limitations due to LCD refresh rate)
Sleeping (end device only)	Red LED is off; “moon” symbol displayed

Table 8-7. LED indication for the RZUSBSTICK devices used in WSNDemo

Node State	LEDs indication
Powered on	Blue LED is on
Searching for network	Red LED blinking
Joined to network	Red LED is on
+ receiving data	Yellow LED
+ sending data to ZigBee network (routers and end devices only)	Green LED
+ sending data to USB (coordinator only)	Green LED
Sleeping	Not supported for RZUSBSTICK

8.5 Reserved Hardware Resources

Table 8-8. Hardware resources reserved by the stack on RZUSBSTICK devices

Resource	Description
Processor main clock	8MHz oscillator with external quartz
SPI	Radio interface
AT90USB1287 ports: PB0, PB1, PB2, PB3, PB4, PB5, PB7, PD4	Radio interface
Timer/Counter3	Radio interface
Timer/Counter1 capture input	Radio interface
Timer/Counter1	System timer

Table 8-9. Hardware resources reserved by the stack on AVRRAVEN devices

Resource	Description
Processor main clock	4 or 8MHz from internal RC-oscillator or external radio frequency
SPI	Radio interface
ATmega ports PB0, PB1, PB3, PB4, PB5, PB6, PB7, PD6	Radio interface
ATmega ports PC6, PC7	Asynchronous timer interface
Timer/Counter2	Asynchronous timer
Timer/Counter3	Radio interface
Timer/Counter1	System timer
Timer1 ICP IRQ	Radio interface
EEPROM	Storage for user settings accessible via Persistent Data Server

9 Appendix A-2: ZigBit Specifics

9.1 Getting Started

9.1.1 Required Hardware

Before installing and using the BitCloud SDK make sure that all necessary hardware is available:

- One or more ATZB-24-B0, ATZB-24-A2, ATZB-A24-UFL, ATZB-A24-U0 modules mounted on PCBs with JTAG connector for programming and UART RS-232 controller for serial communication.
- JTAGICE mkII

9.1.2 Hardware Setup

No special pre-usage assembly is required for MeshBean boards supplied with ZigBit Development Kits.

Please note that the boards can be powered in one of the three ways:

- By a pair of AA-size batteries;
- Via the USB port (once connected for data transfer, see also Section 9.1.4);
- Via an AC/DC adaptor.

The nominal voltage is 3V for MeshBean and MeshBean 900 boards, 3.3V for MeshBean Amp. Using AC/DC adaptor automatically disconnects AA batteries. Using USB port disconnects the AC/DC adaptor.

If you with to demonstrate OTA upgrade functionality, an additional board hosting supported Serial DataFlash™ must be attached to ZigBit as follows:

Table 9-1. `External Flash and MCU pin assignment`

DataFlash™ pin	ATmega1281 MCU pin
`MOSI`	PE1
`MISO`	PE0
`CLOCK`	PE2
`CS`	PF3

9.1.3 System Requirements

Before using the SDK, please ensure that the following system requirements are met by your PC and development environment.

Table 9-2. System requirements for ZigBit, ZigBit Amp and ZigBit 900

Parameter	**Value**	**Note**
CPU	Intel Pentium III or higher, 800MHz	
RAM	128MB	
Free space on hard disk	50MB	

Parameter	Value	Note
JTAG emulator	JTAGICE mkII emulator with cable	Required to upload and debug firmware onto the boards through JTAG (see Section 0).
Operating system	Windows 2000/XP	
IDE	AVR Studio 4.18 Service Pack 2 and WinAVR 20100110 (1) OR IAR Embedded Workbench AVR 5.50 (with IAR C/C++ Compiler for AVR 5.50.0.50277 (2))	Required to upload firmware images through JTAG (see Section 0), and to develop applications using API (see Section 6.2)
Java Virtual Machine	Java Runtime Environment (JRE) 5 Update 8, or later	Required to run WSNMonitor application

Notes: 1,2 Users are strongly recommended to use the specified version of WinAVR and IAR C/C++ Compiler for AVR. Other versions are not supported and may not work.

9.1.4 Installing the SDK

Proceed with the following installation instructions.

1. Download the archive to your PC and unpack it into an empty folder. As a result, the following SDK folders and files will be created with `<SDK-Root>` being the top level SDK folder.

Table 9-3. The SDK file structure

Directory/File	Description
`<SDK-Root>\Documentation`	Documentation on BitCloud software
`<SDK-Root>\Bootloader`	Contains Serial bootloader image file and installer for PC
`<SDK-Root>\Evaluation Tools\WSNDemo (Embedded)`	Ready-to-use image files for evaluating WSNDemo. Refer to section 9.3 for the description of the images.
`<SDK-Root>\Evaluation Tools\WSNDemo (WSN Monitor)\WSNMonitorSetup.exe`	WSN Monitor installer
`<SDK-Root>\Evaluation Tools\SerialNet`	Ready-to-use image files for SerialNet application. Refer to [10] for more information on SerialNet.
`<SDK-Root>\BitCloud\Components`	Header files for BitCloud Stack
`<SDK-Root>\BitCloud\Components\BSP`	Source, header and library files for BitCloud BSP
`<SDK-Root>\BitCloud\lib`	Library files for BitCloud Stack
`<SDK-Root>\Applications`	Source files for sample applications.

2. Install desired IDE:
    a. For AVR Studio and WinAVR:
        i. Install AVR Studio [3], if not already installed on your PC.

ii. Install WinAVR development suite [4], if not already installed on your PC. Be sure to install only the supported version of WinAVR as specified in Table 8-1.

b. For IAR Embedded Workbench AVR:

i. Install IAR Embedded Workbench for AVR [13], if not already installed on your PC.

ii. Add a Windows® environment variable called IAR_AVR_HOME and set its value to the installation directory of IAR Embedded Workbench (for default installation it is "`C:\Program Files\IAR Systems\Embedded Workbench 5.4_0`"). To do this go to `Control Panel > System > Advanced > Environment Variables`, click `New` below `System variables` list and enter `Variable Name` and `Variable Value`. This step is required if you plan to build embedded images using IAR Embedded Workbench from command line.

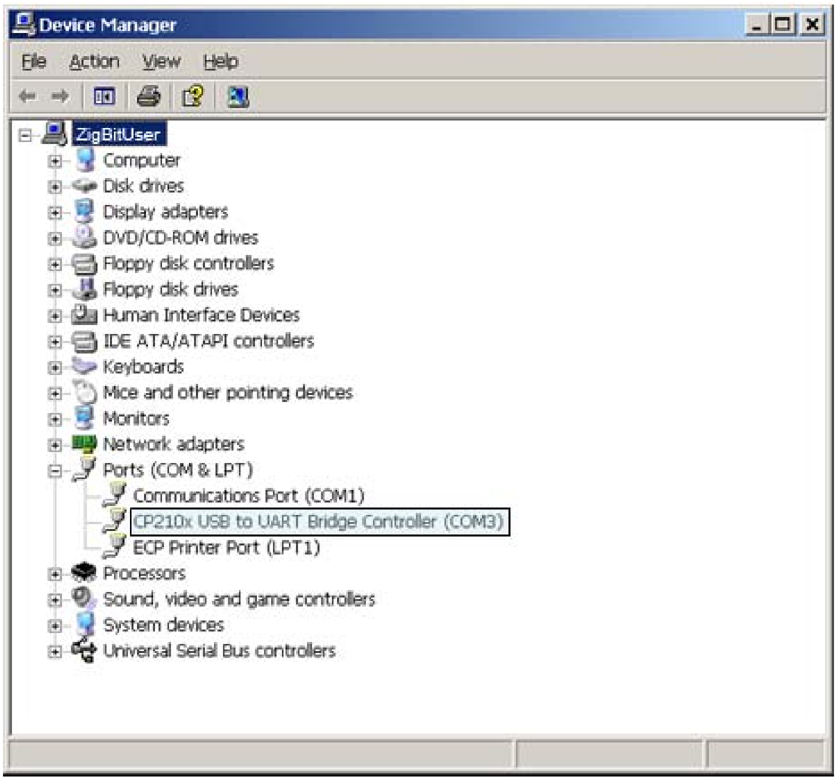
3. The board can be connected to host PC via USB port, using USB 2.0 A/mini-B cable. USB is a familiar connection option. Furthermore, it provides the convenient way to link multiple boards to a single PC, and no battery is required once a board is powered via USB.
4. Alternatively, the board can be connected to host PC via serial port, using a serial cable. Please note that USB and serial port (RS-232) share the same physical port on the board. They cannot be used at the same time. Keep in mind that the connection mode is controlled by setting of jumper on a MeshBean. Refer to Section 9.3 for the description of connectors and jumpers on MeshBean boards.
5. If you plan to use USB connection, install USB to UART Bridge VCP driver. To install the driver, please do the following:

a. Download the driver from https://www.silabs.com/products/mcu/Pages/USBtoUARTBridgeVCPDrivers.aspx

b. Attach the MeshBean board to the USB port of your PC. Windows should detect the new hardware. Follow the instructions provided by the driver installation wizard.

c. Make sure that the driver is installed successfully and the new COM port is present in the device list. Check that the device is correctly shown in the Device Manager window as on the figure below:

Figure 9-1. Correctly installed COM port for MeshBean device



6. Download and install Java Runtime Environment [12], if not already installed on your PC.
7. If OTAU functionality needs to be demonstrate launch `BootloaderOtauSetup.exe` located in `./Bootloader` folder and follow installation instructions.

9.1.5 Configuring Jumpers on MeshBean Boards

This section defines settings for some of the jumpers used on the MeshBean board. For more information on jumper settings and interface pinouts refer to [9]. Note that J2 settings differ for ZigBit, ZigBit 900, and ZigBit Amp.

Table 9-4. `J2` jumper settings for ZigBit and ZigBit 900: power source

Jumper position	Description
J2 bridges `POWER` pin and `BAT` pin	ZigBit is powered by primary source (battery, USB or AC/DC adapter).
J2 bridges `POWER` pin and `DC/DC` pin	ZigBit is powered by 3.6 V internal voltage regulator.

Table 9-5. `J2` jumper settings for ZigBit Amp: power source

Jumper position	Description
J2 bridges pin 2 and pin 3	ZigBit Amp is powered by USB
J2 bridges pin 2 and pin 1	ZigBit Amp is powered by external DC source or by batteries if external DC source is disconnected.

Table 9-6. J3 jumper settings for all MeshBean types: Serial/USB selection

Jumper position	Description
J3 bridges central pin and RS-232 pin	The board will use serial port (available in the Expansion slot) for connection to the host.
J3 bridges central pin and USB pin	The board will use USB for connection to the host.

Warning: Any other position of jumpers J2 and J3 or their omission may permanently damage the MeshBean boards.

9.2 Programming the Boards

9.2.1 Setting Parameters

At startup, the software assigns the 64-bit MAC address to the device as follows. If at compile time `CS_UID` parameter is set to 0, BitCloud attempts to load MAC address from a dedicated UID chip available on MeshBean board via 1-wire interface. If there is no such UID then zero MAC address will be assigned to the device. Note that for proper operation all nodes in the network shall have unique MAC address values. Hence, if address cannot be obtained automatically from external source, separate firmware images shall be created for each device with unique `CS_UID` parameter specified in application configuration (see Section 156.2.1) every time an image is compiled.

9.2.2 Programming

An image file can be uploaded into the boards in one of two ways: using Serial Bootloader utility, or, in AVR Studio, using JTAG emulator.

Each of MeshBean boards provided as a part of ZDK come with the bootstrap uploaded onto the ZigBit's microcontroller, which is needed to run Serial Bootloader. Using a JTAG to program the microcontroller will erase the bootstrap, making the loading of application images with Serial Bootloader impossible until the bootstrap is restored.

To program a board using Serial Bootloader, proceed as follows:

1. Connect MeshBean to the PC via USB or serial port, depending on the position of jumper `J3` (see Section 9.1.5).
2. Run Serial Bootloader. In command line or in GUI, specify the image file as `WSNDemo.srec` and the COM port. See [11].
3. Press reset button on the board. If a node has been configured as end device and it is currently controlled by an application, the node should be powered off before reprogramming.
4. Release reset button on the board. Serial Bootloader expects that the button will be released within approximately 30 seconds. If this does not happen, the booting process will terminate.

Serial Bootloader indicates the operation progress. Once an upload is successfully completed, the board would restart automatically. If an upload fails, Serial Bootloader would indicate the reason. In rare cases, booting process can fail due to the communication errors between the board and the PC. If this happened, attempt booting again or try using conventional serial port, instead of USB. If booting fails, the program written to the board recently would be corrupted, but the board can be reprogrammed again as the bootstrap should remain intact.

Refer to AVR Studio documentation for the description of how the images can be programmed to the boards using JTAG.

Set the following options in the Fuses tab before uploading the image through JTAG.

Table 9-7. Fuse bits setting for ZigBit, ZigBit Amp, ZigBit 900

Option	Value
BODLEVEL	Brown-out detection disabled
OCDEN	Disabled
JTAGEN	Enabled
SPIEN	Enabled
WDTON	Disabled
EESAVE	Disabled
BOOTSZ	Boot Flash size=1024 words start address=$FC00
BOOTRST	Disabled* If the node is to be programmed with the use of Serial Bootloader, enable the BOOTRST option.
CKDIV8	Enabled
CKOUT	Disabled
SUT_CKSEL	Int. RC Osc.; Start-up time: 6 CK + 65 ms

Make sure the following hex values appear in the bottom part of `Fuses` tab:

```
0xFF, 0x9D, 0x62.
```

If the node is to be programmed with the use of Serial Bootloader, enable additionally the `BOOTRST` option. Make sure the following hex value string appears at the bottom of Fuses tab:

```
0xFF, 0x9C, 0x62.
```

9.3 Pre-Built Images

The SDK comes with the ready-to-use binary images in `.hex` format for programming using JTAG and in `.srec` format if using Serial Bootloader [11].

- WSN Demo Application
    - `WSNDemoApp_RF230.hex` – for ZigBit (ATZB- ATZB-24-B0, ATZB-24-A2)
    - `WSNDemoApp_RF230_Amp.hex` – ZigBit Amp (ATZB-A24-UFL)
    - `WSNDemoApp_RF212China.hex`, `WSNDemoApp_RF212US.hex` and `WSNDemoApp_RF212EU.hex` – ZigBit 900 (ATZB-900-B0)
- SerialNet Application
    - `SerialNet_RF230.hex` – for ZigBit (ATZB- ATZB-24-B0, ATZB-24-A2)
    - `SerialNet_RF230_Amp.hex` – ZigBit Amp (ATZB-A24-UFL)
    - `SerialNet_RF212US.hex` – ZigBit 900 (ATZB-900-B0)

- Runner Application
  - o `Runner_RF230.hex` – for ZigBit (ATZB- ATZB-24-B0, ATZB-24-A2)
  - o `Runner_RF230_Amp.hex` – ZigBit Amp (ATZB-A24-UFL)
  - o `Runner_RF212US.hex` – ZigBit 900 (ATZB-900-B0)

The ready-to-use binary images retrieve MAC address automatically from UID ensuring that unique MAC addresses are assigned to all network nodes.Also note that the default WSNDemo application images are configured to use Extended PAN ID `0x`AAAAAAAAAAAAAAAA and channel mask with:

- Channel `0x0F` enabled for ZigBit and ZigBit Amp (`WSNDemoApp.hex`),
- Channel `0x00` and channel page 0 (`WSNDemoApp_EU.hex`) or channel `0x01` and channel page `0` (`WSNDemoApp_RF212US.hex`) for ZigBit 900,
- Channel `0x01` and channel page 5 (`WSNDemoApp_China.hex`) for ZigBit 900.

9.3.1 Starting WSNDemo

To start WSNDemo, proceed as follows:

1. Setup the hardware as described in Section 9.1.2.
2. Install BitCloud SDK as described in Section 9.1.4
3. Program devices as described in section 9.2.
4. Configure one single node as a coordinator, and make the others be routers and end devices (see Section 9.3.2). Any of the boards provided can be configured with any role.
5. Connect the coordinator node to the PC, using USB port on the coordinator board
6. Power on the coordinator node
7. Run WSN Monitor (see Section 5.5)
8. Power ON and reset the rest of the nodes.

9.3.2 Node Role Configuration

The role of the node – coordinator, router, or end-device is configured using DIP switches on MeshBean board.

Note: When WSN Demo is loaded on a board other than a MeshBean special care must be taken to reconfigure the application to not read off node roles from DIP switches at application initialization. The roles can be hard-coded or read off any other peripheral available on the custom board.

Table 9-8. DIP switches configurations on MeshBean boards used in WSNDemo

DIP Switches			Selected Role
1	2	3	
ON	OFF	OFF	Coordinator
OFF	ON	OFF	Router
OFF	OFF	ON	End-Device

9.3.3 Monitoring WSNDemo Activity

Network activity can be monitored in two ways:

- Observing color LEDs of MeshBean boards (see the table below);

- Monitoring network topology and configuration through WSN Monitor installed on PC.

Table 9-9. LED indication for MeshBean boards used in WSNDemo

Node State	LED1 (Red)	LED2 (Yellow)	LED3 (Green)
Searching for network	Blinking	OFF	OFF
Joined to network	ON		
+ receiving data		Blinking	
+ sending data to UART (coordinator only)			Blinking
Sleeping (end device only)	OFF	OFF	OFF

Note: When WSN Demo runs on a board other than a MeshBean, special care must be taken to reconfigure the application to output networking state to available user interfaces (e.g. LEDs).

9.3.4 Over-the-air Upgrade Configuration

Over-the-air upgrade functionality of BitCloud can be demonstrated using ZigBit platform. This demonstration requires additional hardware, namely:

- A dedicated device running Runner application and performing the function of an Over-the-Air Upgrade Client
- One of the supported external DataFlash™ device is connected to ZigBit module as described in Section 9.1.2 and used to store uploaded application images.

Note: Only those modules that have a DataFlash connected to them should be programmed with OTAU-capable WSN Demo application. The rest can run the stock WSN Demo firmware.

Once the external DataFlash™ is connected to the board, the user should configure and install devices as follows:

1. Load WSNDemo application configured and compiled with `APP_USE_OTAU` defined as 1 under project in `iarConfiguration.h` file or Configuration file.
    a. Program serial bootloader bootstrap `bootloaderOTAU_ATmega1281.hex` located in `<SDK-Root>\Bootloader` folder of SDK according to platform specific instructions.
    b. Application image should be converted to `*.srec` format and installed using serial bootloader interface as described in Section 5.5.3.The device is now able to perform the function of OTA client as defined in [29]. The above process should be repeated for every node that the user intends to upgrade over the air.
2. Program another device with Runner application available in `<SDK-Root>\Evaluation Tools\Runner\` directory in SDK. The device is now able to perform the function of OTA server as defined in [29]. Once the images are programmed and WSNDemo devices are joined to the network follow instructions given in 5.5.3 to update firmware over the air.

9.4 Reserved Hardware Resources

Table 9-10. Hardware resources reserved by the stack on ZigBit, ZigBit Amp, and ZigBit 900 modules

Resource	Description
Processor main clock	8 MHz from internal RC-oscillator or external radio frequency
SPI	Radio interface
ATmega ports PB0, PB1, PB2, PB3, PB4, PA7, PE5	Radio interface
ATmega port PC1	Interface for amplifier (if present)
ATmega ports PG3, PG4	Asynchronous timer interface
Timer/Counter 2	Asynchronous timer
Timer/Counter 4	System timer
External IRQ4	Wake-up on DTR
External IRQ5	Radio interface
EEPROM	Storage for user settings accessible via Persistent Data Server
PE0..PE2, PF3	External DataFlash™, when OTAU functionality is used

10 Appendix A-3: ATmega128RFA1 Specifics

10.1 Getting Started

BitCloud supports two different development platforms with ATmega128RFA1: α-package development kit [14] and STK600 boards [15]. Instructions below will highlight the differences between the two platform configurations, where present.

10.1.1 Required Hardware

Before installing and using the BitCloud SDK for ATmega128RFA1 make sure that all necessary hardware is available:

- For α-package
  - o Two or more RCB128RFA1 boards with 2.4GHz antennas and AAA batteries
  - o one or more RCB Breakout Boards
  - o one RS232 interface cable for RCB Breakout Board
  - o JTAGICE mkII
- For STK600 boards
  - o Two or more STK600 boards, each with Atmega128RFA1 top card and 2.4GHz antenna
  - o JTAGICE mkII

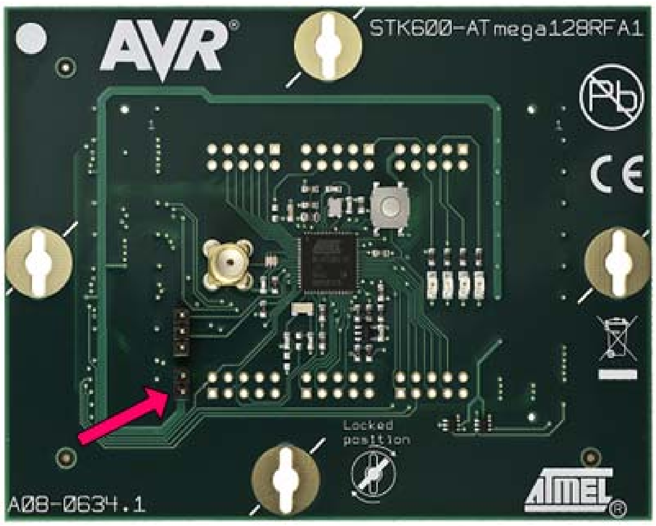
10.1.2 Hardware Setup

For α-package please refer to [14] for hardware setup instructions.

STK600-ATmega128RFA1 top cards require following modifications:

1. Make sure jumper is present at pins as indicated by red arrow on Figure 10-1.

Figure 10-1. Jumper setting for STK600-ATmega128RFA1 top card.



2. Assemble top card with STK600 board.
3. Default output for USART interface is performed via PD2, PD3 pins. In order to communicate over RS232 port they shall be connected to RXD and TXD pins of RS232 SPARE port respectively.

Before continuing any further operations, perform the steps required to get started with ATSTK6000 [15]. Refer to AVR Studio Help [3] for details on that subject. At the very least, make sure that STK600 firmware is up-to-date, and configure the voltage provided by STK600 for ATmega128RFA1 top card. For that, perform the following steps:

1. Attach STK600 to PC using USB cable.
2. In AVR Studio open `Tools > Program AVR > Connect…` dialogue
3. Choose the right Platform = STK600 and press Connect.
4. Update the STK600 firmware, if suggested.
5. Go to HW Settings tab.
6. Specify the 3.3V in the VTarget field and press Write

The above actions must be performed once for each ATSTK600 board.

If you with to demonstrate OTA upgrade functionality using this hardware configuration, Serial DataFlash™ device (AT45DB041) hosted on STK600 must be connected to ATmega128RFA1 ports as follows:

Table 10-1. External Flash and MCU pin assignment

DataFlash™ pin	ATmega128RFA1 MCU pin
`MOSI`	PE1
`MISO`	PE0
`CLOCK`	PE2
`CS`	PG5

10.1.3 System Requirements

Before using the SDK, please ensure that the following system requirements are met by your PC and development environment.

Table 10-2. System requirements for Atmega128RFA1

Parameter	**Value**	**Note**
CPU	Intel Pentium III or higher, 1GHz	
RAM	512MB	
Free space on hard disk	200MB	
JTAG emulator	JTAGICE mkII emulator with cable	Required to upload and debug firmware onto the boards through JTAG (see Section 0).
Operating system	Windows 2000/XP	

Parameter	Value	Note
IDE	AVR Studio 4.18 Service Pack 2 and WinAVR 20100110 (1) OR IAR Embedded Workbench AVR 5.50.0 (with IAR C/C++ Compiler for AVR 5.50.0.50277 (2))	Required to upload firmware images through JTAG (see Section 0), and to develop applications using API (see Section 6.2)
Java Virtual Machine	Java Runtime Environment (JRE) 5 Update 8, or later	Required to run WSNMonitor application

Notes: 1. Users are strongly recommended to use the specified version of WinAVR. Other versions are not supported and may not work.

10.1.4 Installing the SDK

Proceed with the following installation instructions:

1. Download the archive to your PC and unpack it into an empty folder with no blank spaces present in the directory path. As a result, the following SDK folders and files will be created.

Table 10-3. The SDK file structure

Directory/File	Description
`<SDK-Root>\Documentation`	Documentation on BitCloud software
`<SDK-Root>\Bootloader`	Contains serial bootloader image file and installer for PC
`<SDK-Root>\Evaluation Tools\WSNDemo (Embedded)`	Ready-to-use image files for evaluating WSNDemo. Refer to section 0 for the description of the images.
`<SDK-Root>\Evaluation Tools\WSNDemo (WSN Monitor)\WSNMonitorSetup.exe`	WSN Monitor installer
`<SDK-Root>\BitCloud\Components\`	Header files for BitCloud Stack
`<SDK-Root>\BitCloud\Components\BSP\`	Source, header and library files for BitCloud BSP
`<SDK-Root>\BitCloud\lib`	Library files for BitCloud Stack
`<SDK-Root>\Applications`	Source files for sample applications.

2. Install desired IDE:
   a. For AVR Studio and WinAVR:
      i. Install AVR Studio [3], if not already installed on your PC.
      ii. Install WinAVR development suite [4], if not already installed on your PC. Be sure to install only the supported version of WinAVR as specified in Table 8-1.
   b. For IAR Embedded Workbench AVR:
      i. Install IAR Embedded Workbench for AVR [13], if not already installed on your PC.
      ii. Add a Windows® environment variable called IAR_AVR_HOME and set its value to the installation

directory of IAR Embedded Workbench (for default installation it is “C:\Program Files\IAR Systems\Embedded Workbench 5.4_0”). To do this go to Control Panel > System > Advanced > Environment Variables, click New below System variables list and enter Variable Name and Variable Value. This step is required if you plan to build embedded images using IAR Embedded Workbench from command line.

3. Download and install Java Runtime Environment [12], if not already installed on your PC.
4. If OTAU functionality needs to be demonstrate launch BootloaderOtauSetup.exe located in ./Bootloader folder and follow installation instructions.

10.2 Programming the Boards

10.2.1 Setting Parameters

At startup, the software assigns the 64-bit MAC address to the device as follows. If at compile time CS_UID parameter is set to 0, BitCloud attempts to load MAC address from a dedicated external EEPROM chip available on RCB128RFA1 as well as on Atmega128RFA1 top card via SPI interface. If there is no such chip then zero MAC address will be assigned to the device. Note that for proper operation all nodes in the network shall have unique MAC address values. Hence, if address cannot be obtained automatically from external source, separate firmware images shall be created for each device with unique CS_UID parameter specified in application configuration (see Section 6.2.1) every time an image is compiled.

10.2.2 Programming

An image file can be uploaded into the boards in one of two ways: using Serial Bootloader utility or using JTAG emulator.

Programming a board using Serial Bootloader requires that bootstrap is loaded to the device via JTAG. For RCB128RFA1 with RCB breakout board Bootloader_ATmega128RFA1_RCB_BB.hex image file shall be flashed via JTAG. For STK600 Bootloader_ATmega128RFA1.hex file shall be loaded to ATmega128RFA1. In both cases the fuse bit configuration specified in Table 10-4 BOOTRST should be enabled. If bootstrap is loaded following steps should be executed to upload the application image file to the board:

1. Assemble board and connect it to PC:
    a. For RCB128RFA1:
        i. Assemble RCB128RFA1 and RCB Breakout boards (RCB_BB) together.
        ii. Connect RS232 interface cable to J1 extender on RCB_BB and COM1 port on the PC.
    b. For STK600:
        i. Assemble STK600 board and ATmega128RFA1 top card as described in Section 10.1.2.
        ii. Connect PC COM1 port to RS232 SPARE port.

2. Run Serial Bootloader application on the PC. In command line or in GUI, specify the .srec image file and the COM port. See [11].
3. Perform HW reset on the board if requested. Serial Bootloader expects that the reset will be done within 30 seconds. If this does not happen, the booting process will terminate.
4. Serial Bootloader will show upload progress. Once upload is successfully completed, the board would restart automatically. If an upload fails, Serial Bootloader would indicate the reason. In rare cases, booting process can fail due to the communication errors between the board and the PC. If this happens, attempt upload again. If booting fails, the last program written to the board would be corrupted, but the board can be reprogrammed again as the bootstrap should remain intact.

Refer to [14] and [15] for the description of how the images can be programmed to corresponding development boards using JTAG. Note that using a JTAG to program the microcontroller will erase the bootstrap if present, thus loading of application images with Serial Bootloader will become inoperable until the bootstrap is loaded to ATmega128RFA1 again.

Set the following options in the Fuses tab before uploading the image through JTAG.

Table 10-4. Fuse bits setting for ATmega128RFA1

Option	Value
BODLEVEL	Brown-out detection at VCC=1.8 V
OCDEN	Disabled
JTAGEN	Enabled
SPIEN	Enabled
WDTON	Disabled
EESAVE	Disabled
BOOTSZ	Boot Flash size=1024 words start address=$FC00
BOOTRST	Disabled* If the node is to be programmed with the use of Serial Bootloader, enable the BOOTRST option.
CKDIV8	Enabled
CKOUT	Disabled
SUT_CKSEL	Int. RC Osc.; Start-up time: 6 CK + 65 ms

Make sure the following hex values appear in the bottom part of `Fuses` tab:

```
0xFE, 0x9D, 0x62.
```

If the node is to be programmed with the use of Serial Bootloader, enable additionally the BOOTRST option. Make sure the following hex value string appears at the bottom of Fuses tab:

```
0xFE, 0x9C, 0x62.
```

10.3 Pre-Built Images

The SDK comes with the following ready-to-use binary images that can be used on STK600 or RCB128RFA1 boards:

- WSNDemoApp_Coord.hex, WSNDemoApp_Coord.srec – for Coordinator node
- WSNDemoApp_Router.hex, WSNDemoApp_Router.srec – for Router nodes
- WSNDemoApp_EndDev.hex, WSNDemoApp_EndDev.srec – for End Device nodes
- Runner_megaRF_STK600RCB.hex – for Server side of OTAU Cluster.

These .hex files should be loaded using JTAG, while .srec files can be flashed using Serial Bootloader. In all ready-to-use binary images MAC address (CS_UID) is loaded automatically from a dedicated external EEPROM chip, ensuring that unique values are assigned to all network nodes. Note that the default WSNDemo images are configured to use Extended PAN ID 0xAAAAAAAAAAAAAAAA and channel mask with only channel 0x0F enabled for operation.

10.4 Running WSNDemo

10.4.1 Starting WSNDemo

To start WSNDemo, proceed as follows:

1. Setup the hardware as described in Section 10.1.2
2. Install BitCloud SDK as described in Section 10.1.4
3. Program one device with coordinator image file and other with either router or end device images as described in Section 10.2
4. Connect the coordinator node to the PC, using serial interface
5. Power on the coordinator node
6. Run WSN Monitor (see Section 5.5)
7. Power ON and reset the rest of the nodes.

10.4.2 Monitoring WSNDemo Activity

Network activity can be monitored in two ways:

- Observing LEDs of the development boards as described in Table 10-5. LED Dx label corresponds to RCB128RFA1 board, and color label to STK600 board.
- Monitoring the network topology through WSN Monitor installed on PC (see Section 5.5).

Table 10-5. LED indication for RCB128A1 boards used in WSNDemo

Node State	LED D2 (red)	LED D3 (yellow)	LED D4 (green)
Searching for network	Blinking	OFF	OFF
Joined to network	ON		
+ receiving data		Blinking	
+ sending data to UART (coordinator only)			Blinking
Sleeping (end device only)	OFF	OFF	OFF

10.4.3 Demonstrating OTA Upgrade functionality

OTA upgrade functionality of BitCloud can be demonstrated using megaRF platform by using a Serial DataFlash™ device found on STK600 board. Once DataFlash™ is connected to ATmega128RFA1 as defined in Section 10.1.2, the user should configure and install devices as follows:

1. Load WSNDemo application configured and compiled with `APP_USE_OTAU` defined as 1 under project in `iarConfiguration.h` file.
    a. Program serial bootloader bootstrap `bootloaderOTAU_ATmega128RFA1.hex` located in `<SDK-Root>\Bootloader` folder of SDK according to platform specific instructions.
    b. Application image should be converted to `*.srec` format and installed using serial bootloader interface as described in Section 5.5.3.
    c. Device is able to act as OTA client as defined in [29].
2. Program another device with Runner application available in `<SDK-Root>\Evaluation Tools\Runner\` directory in SDK.
    a. Runner node acts as OTA server as defined in [29].

Once the images are programmed and WSNDemo devices are joined to the network follow instructions given in 5.5.3 to update firmware over the air.

10.5 Reserved Hardware Resources

Table 10-6. Hardware resources reserved by the stack on Atmega128RFA1

Resource	Description
Processor main clock	8 MHz from internal RC-oscillator
TRX24	Radio
ATmega ports PG3, PG4	Asynchronous timer interface
Timer/Counter 2	Asynchronous timer
Timer/Counter 4	System timer
External IRQ4	Wake-up on DTR
EEPROM	Storage for user settings accessible via Persistent Data Server
PE0..PE2, PG5	External DataFlash™, when OTAU functionality is used

11 Appendix A-4: UC3 Specifics

11.1 Getting Started

11.1.1 Required Hardware

Before installing and using the BitCloud SDK for 32-bit AVR UC3 make sure that all necessary hardware is available:

1. Two or more EVK1105 boards [17]
2. Two or more radio extender boards [16]
3. All necessary connectors
4. JTAGICE mkII

11.1.2 Hardware Setup

To prepare the hardware:

1. Install `J12` and `J16` extension headers on the board (if not already installed)
2. Install JTAG pin header on the board (if not already installed)
3. Use several 2-wire cables to connect `J16` pins to corresponding pins on REB231 boards as indicated in Table 11-1.

Table 11-1. EVK1105 to Radio Extender Board REB231 pin mapping

EVK1105 J16 pin	REB231 pin
1	30
2	29
3	28
4	27
5	38
6	26
8	25
9	22
10	20

11.1.3 System Requirements

Before using the SDK, please ensure that the following system requirements are met by your PC and development environment.

Table 11-2. System requirements for UC3

Parameter	Value	Note
CPU	Intel Pentium III or higher, 1GHz	
RAM	512MB	
Free space on hard disk	200MB	

Parameter	Value	Note
JTAG emulator	JTAGICE mkII emulator with cable	Required to upload and debug firmware onto the boards through JTAG (see Section 0).
Operating system	Windows 2000/XP	
IDE	IAR Embedded Workbench 32-bit AVR (with IAR C/C++ Compiler for 32-bit AVR 3.30.1.40051(1)) and 32-bit AVR GNU Toolchain v2.3	Required to upload firmware images through JTAG (see Section 0), and to develop applications using API (see Section 6.2). 32-bit AVR GNU Toolchain is only needed to install USB VCP driver.
Java Virtual Machine	Java Runtime Environment (JRE) 5 Update 8, or later	Required to run WSNMonitor application

Notes: 1. Users are strongly encouraged to use specified versions of IAR C/C++ Compiler for 32-bit AVR. Other versions are not supported and may not work.

11.1.4 Installing the SDK

Proceed with the following installation instructions:

1. Download the archive to your PC and unpack it into an empty folder with no blank spaces present in the directory path. As a result, the following SDK folders and files will be created.

Table 11-3. The SDK file structure

Directory/File	Description
`<SDK-Root>\Documentation`	Documentation on BitCloud software
`<SDK-Root>\Evaluation Tools\WSNDemo (Embedded)`	Ready-to-use image files for evaluating WSNDemo. Refer to section 0 for the description of the images.
`<SDK-Root>\Evaluation Tools\WSNDemo (WSN Monitor)\`	Contains WSN Monitor installer
`<SDK-Root>\BitCloud\Components\`	Header files for BitCloud Stack
`<SDK-Root>\BitCloud\Components\BSP\`	Source, header and library files for BitCloud BSP
`<SDK-Root>\BitCloud\lib`	Library files for BitCloud Stack
`<SDK-Root>\Sample Applications\`	Source files for sample applications.

2. Install IAR Embedded Workbench for 32-bit AVR [20], if not already installed on your PC. Be sure to install only the supported version of IAR Embedded Workbench as specified in Table 11-2.

   i. Add a Windows® environment variable called IAR_AVR32_HOME and set its value to the installation directory of IAR Embedded Workbench (for default installation it is “`C:\Program Files\IAR Systems\Embedded Workbench 5.4_0`”). To do this go to `Control Panel > System > Advanced > Environment Variables`, click `New` below `System variables` list and enter `Variable Name` and `Variable`

`Value`. This step is required if you plan to build embedded images using IAR Embedded Workbench from command line.

3. Install 32-bit AVR GNU Toolchain [19], if not already installed on your PC.
4. Download and install Java Runtime Environment [12], if not already installed on your PC.
5. Install USB VCP driver on EVK1105 to allow it to communicate with your PC.
   a. Connect JTAG to UC3B JTAG header, and power on the board.
   b. From `Third Party Software\EVK1105_UC3B_VCP` run `program_evk1105_at32uc3b-isp-cdc-1.0.1.cmd` Windows command script.
   c. VCP driver should now be installed on the board.
6. Attach EVK1105 board to the USB port of your PC using USB 2.0 A/mini-B cable. Windows should detect the new hardware. Follow the instructions provided by the driver installation wizard. When prompted, choose to install the driver from the specific location, and select the driver located in `Third Party Software` folder of the SDK.

11.2 Programming the Boards

11.2.1 Setting Parameters

For proper operation all nodes in ZigBee network shall have unique MAC address values. For UC3 a unique `CS_UID` parameter must be specified for each node in the application configuration (see details in Section 6.2.1), and then the application image must be built separately for each board.

11.2.2 Programming

An image file from existing project for IAR Embedded Workbench for 32-bit AVR can be uploaded into the boards using JTAG emulator as follows:

1. Assemble board and connect it to PC:
2. Connect JTAG to UC3A JTAG header. Power on the board and JTAG ICE mkII.
3. Start IAR Embedded Workbench for 32-bit AVR
4. From `File -> Open -> Workspace` navigate to and open desired IAR project (e.g. `WSNDemoApp.eww` file in `Sample Applications\WSNDemo\iar\avr32` folder).
5. Select `Project -> Download and Debug`
6. Once the firmware is loaded, select `Debug -> Stop Debugging`
7. Unplug JTAG from UC3A JTAG header.
8. Reset EVK1105.

Alternatively it is possible to load ready image file in .elf format using 32-bit AVR GNU Toolchain [19] by running following command in console:

```
avr32program program -finternal@0x80000000,256Kb -cxtal -e -v
-O0x80000000 <filename.elf>
```

Make sure the following fuse options in `JTAGICE mkII -> Fuse` handler menu of IAR Embedded Workbench for 32-bit AVR are set.

Table 11-4. Fuse bits setting for AT32UC3A0512

Option	Value
BODLEVEL	Brown-out detection at VCC=1.92 V (63)
BODHYST	Enabled (1)
BODEN	Disabled (3)
LOCK0 – LOCK15	Unlocked (1)
EPFL	External instruction fetch enabled (1)
BOOTPROT	No bootloader (7)
GF29	1
GF30	1
GF31	1

11.3 Pre-Built Images

The SDK comes with ready-to-use binary images of WSN Demo application. There is a set of images for different roles pre-configured with different MAC addresses so that can be used for creating a small ZigBee network right away.

- `WSNDemoApp_Coord_RF231.elf` – for EVK1105 node with RZ600 radio stick based on RF231, acting as Coordinator
- `WSNDemoApp_Router_RF231.elf` – for EVK1105 node with RZ600 radio stick based on RF231, acting as Router
- `WSNDemoApp_EndDev_RF231.elf` – for EVK1105 node with RZ600 radio stick based on RF231, acting as End Device
- `WSNDemoApp_Coord_RF212US.elf` – for EVK1105 node with RZ600 radio stick based on RF212, acting as Coordinator
- `WSNDemoApp_Router_RF212US.elf` – for EVK1105 node with RZ600 radio stick based on RF212, acting as Router
- `WSNDemoApp_EndDev_RF212US.elf` – for EVK1105 node with RZ600 radio stick based on RF212, acting as End Device
- `WSNDemoApp_Coord_RF230.elf` – for EVK1105 node with RZ600 radio stick based on RF230, acting as Coordinator
- `WSNDemoApp_Router_RF230.elf` – for EVK1105 node with RZ600 radio stick based on RF230, acting as Router
- `WSNDemoApp_EndDev_RF230.elf` – for EVK1105 node with RZ600 radio stick based on RF230, acting as End Device

Note: Default images are pre-configured to use Extended PAN ID `0xAAAAAAAAAAAAAAAA` and operate on channel `0x0F` (for RF231 and RF230 radios) or channel `0x01` and channel page 0 (for RF212 radio).

11.4 Running WSNDemo

11.4.1 Starting WSNDemo

To start WSNDemo, do the following:

1. Setup the hardware as described in Section 11.1.2

2. Install BitCloud SDK as described in Section 11.1.4
3. Program one device with coordinator image file and other with either router or end device images as described in Section 11.2
4. Connect the coordinator node to the PC, using serial interface
5. Power on the coordinator node
6. Run WSN Monitor (see Section 5.5)
7. Power ON and reset the rest of the nodes.

11.4.2 Monitoring WSNDemo Activity

Network activity can be monitored in two ways:

- Observing LEDs of the development boards as described in Table 11-5. LEDx label corresponds to EVK1105 board.
- Monitoring network topology information through WSN Monitor installed on PC (see Section 5.5).

Table 11-5. LED indication for WSNDemo application on EVK1105 board

Node State	LED0	LED1	LED2
Searching for network	Blinking	OFF	OFF
Joined to network	ON		
+ receiving data		Blinking	
+ sending data to UART (coordinator only)			Blinking
Sleeping (end device only)	OFF	OFF	OFF

11.5 Reserved Hardware Resources

Table 11-6. Hardware resources reserved by the stack on AT32UC3A0512

Resource	Description
Processor main clock	48 MHz from external quartz
32-bit AVR ports A9, A20, A11, A12, A13	Radio interface
Timer Channel 0	Timer
32-bit AVR port B30, B31	Sleep / reset

12 Appendix A-5. ATxmega Specifics

12.1 Getting Started

12.1.1 Required Hardware

Before installing and using BitCloud SDK make sure that all necessary hardware is available for the kit you would like to use:

- Two or more ATSTK600s . For each, additionally:
  - Routing card for ATxmega256A3 and ATxmega256D3 AVR microcontrollers
  - Selected MCU (either ATxmega256A3 or ATxmega256D3)
  - RZ600 radio board
- JTAGICE mkII (XMEGA PDI Adapter for JTAGICE mkII is required for ATxmega256D3 device)

12.1.2 Hardware Setup

1. Attach ATxmega socket card and routing card to STK600.
2. If RZ600 radio boards are used, attach the board to PORTC on STK600. Be sure to note the type of radio stick (RF231 or RF230 or RF212) connected to ensure compatible firmware is chosen in the later steps
3. Connect LEDs to the ATxmega expansion board. By default, applications provided with the SDK assume that the LEDs are connected through `PORTE` (defined in "`<SDK-Root>\BitCloud\Components\BSP\ATML_STK600\include\bspLeds.h`"). Connect PORTE on ATxmega board with LEDS connector on STK600 using a 10-wire cable.
4. Route ATxmega UART to RS232 port on STK600 board. The current revision of SDK uses asynchronous mode without hardware flow control (`RXD` and `TXD` pins only) on `PORTF` USART 0. Use 2-wire cable to connect `PORTF` pins 2 and 3 with RS232 SPARE connector: `PF2` with `RXD`, `PF3` with `TXD`.
5. Before performing any further operations, perform the steps required to get started with ATSTK6000 [15]. Refer to AVR Studio Help for details on that subject. At least, make sure that STK600 firmware is up-to-date, and configure the voltage provided by STK600 for ATxmega socket card. For that, perform the following steps:
   a. Attach STK600 to PC using USB cable.
   b. In AVR Studio open `Tools > Program AVR > Connect…` dialogue
   c. Choose the right Platform = STK600 and press `Connect`.
   d. Update the STK600 firmware, if suggested.
   e. Go to `HW Settings` tab.
   f. Specify the required voltage in the VTarget field and press `Write`. Please note that the voltage should be less than 3.6V – for example, 3.0V.

You need to perform this procedure once for each ATSTK600 board.

If you with to demonstrate OTA upgrade functionality using this hardware configuration, Serial DataFlash™ device (AT45DB041) hosted on STK600 must be connected to ATxmega256A3/D3 ports as follows:

Table 12-1. `External Flash and MCU pin assignment`

DataFlash™ pin	ATxmega256A3/D3 MCU pin
`MOSI`	PD5
`MISO`	PD6
`CLOCK`	PD7
`CS`	PD4

12.1.3 System Requirements

Before using the SDK, please ensure that the following system requirements are met by your PC and development environment.

Table 12-2. System requirements for ATSTK600

Parameter	Value	Note
CPU	Intel Pentium III or higher, 800MHz	
RAM	128MB	
Free space on hard disk	50MB	
JTAG emulator	JTAGICE mkII emulator with cable	Required to upload and debug firmware onto the boards through JTAG (see Section 0).
Operating system	Windows 2000/XP	
IDE	AVR Studio 4.18 Service Pack 2 and WinAVR 20100110 (1) OR IAR Embedded Workbench AVR 5.50.0 (with IAR C/C++ Compiler for AVR 5.50.0.50277 (2))	Required to upload firmware images through JTAG (see Section 0), and to develop applications using API (see Section 6.2)
Java Virtual Machine	Java Runtime Environment (JRE) 5 Update 8, or later	Required to run WSNMonitor application

Notes: 1,2 Users are strongly encouraged to use specified versions of WinAVR and IAR C/C++ Compiler for AVR. Other versions are not supported and may not work.

12.1.4 Installing the SDK

Proceed with the following installation instructions.

1. Download the archive to your PC and unpack it into an empty folder. As a result, the following SDK folders and files will be created.

Table 12-3. The SDK file structure

Directory/File	Description
`<SDK-Root>\Documentation`	Documentation on BitCloud software
`<SDK-Root>\Evaluation Tools\WSNDemo (Embedded)`	Ready-to-use image files for evaluating WSNDemo. Refer to section 12.3 for the description of the images.
`<SDK-Root>\Evaluation Tools\WSNDemo (WSN Monitor)\WSNMonitorSetup.exe`	WSN Monitor installer
`<SDK-Root>\BitCloud\Components`	Header files for BitCloud Stack
`<SDK-Root>\BitCloud\Components\BSP\`	Source, header and library files for BitCloud BSP
`<SDK-Root>\BitCloud\lib`	Library files for BitCloud Stack
`<SDK-Root>\Sample Applications\`	Source files for sample applications.

2. Install selected IDE
   a. For AVR Studio and WinAVR:
      i. Install AVR Studio [3], if not already installed on your PC.
      ii. Install WinAVR development suite [4], if not already installed on your PC. Be sure to install only the supported version of WinAVR as specified in Table 12-2.
   b. For IAR Embedded Workbench AVR:
      i. Install IAR Embedded Workbench for AVR [13], if not already installed on your PC.
      ii. Add a Windows® environment variable called IAR_AVR_HOME and set its value to the installation directory of IAR Embedded Workbench (for default installation it is "`C:\Program Files\IAR Systems\Embedded Workbench 5.4_0`"). To do this go to `Control Panel > System > Advanced > Environment Variables`, click `New` below `System variables` list and enter `Variable Name` and `Variable Value`. This step is required if you plan to build embedded images using IAR Embedded Workbench from command line.
3. Download and install Java Runtime Environment [12], if not already installed on your PC.
4. If OTAU functionality needs to be demonstrate launch `BootloaderOtauSetup.exe` located in `./Bootloader` folder and follow installation instructions.

12.2 Programming the Boards

12.2.1 Setting Parameters

For proper operation all nodes in ZigBee network shall have unique MAC address values. On XMEGA platform a unique `CS_UID` parameter must be specified for each node in the application configuration (see details in Section 6.2.1), and then the application image must be built separately for each board.

12.2.2 Programming

Refer to AVR Studio [3] and IAR Embedded Workbench [13] documentation for the description of how the images can be programmed to the boards using JTAG.

Please note that JTAGICE must be connected to a particular JTAG connector on STK600. This connector is not marked with any label and is situated next to the connector marked as JTAG (in the blue background area) but closer to the ATxmega expansion board. ATxmega256D3 devices only support PDI programming. The PDI connector can be found next to JTAG connector on STK600 board. A special XMEGA PDI adapter must be used with JTAG for programming ATxmega256D3 devices.

Make sure that the board and ATxmega socket card are powered on (refer to Section 12.1.2 for the description of additional steps required for that) and set the right options in the Fuses tab (see the table below) before uploading the image through JTAG. Don't forget to select the right device (ATxmega256A3 or ATxmega256D3) in the Device and Signature Bytes field on the Main tab of the programming dialogue. After programming the image reset the STK600 board.

Table 12-4. Fuse bits setting for ATxmega256A3

Option	Value
JTAGUSERID	0xFF
WDWP	8 cycles (8 ms @ 3,3V)
WDP	8 cycles (8 ms @ 3,3V)
DVSDON	OFF
BOOTRST	Application Reset
BODACT	BOD Disabled
BODPD	BOD Disabled
SUT	0 ms
WDLOCK	OFF
JTAGEN	ON
EESAVE	OFF
BODLVL	1.6V
Resulting bytes:	
FUSEBYTE0	*0xFF*
FUSEBYTE1	*0x00*
FUSEBYTE2	*0xFF*
FUSEBYTE4	*0xFE*
FUSEBYTE5	*0xFF*

12.3 Pre-Built Images

The SDK comes with ready-to-use binary images of WSNDemo application. There is a set of images for different roles and pre-configured with different MAC addresses, so they can be used for creating a small ZigBee network right away.

- `WSNDemoApp_Coord_RF230.hex` – for STK600/ATxmega256A3 and RZ600 radio stick with RF230 onboard, acting as Coordinator
- `WSNDemoApp_Router_RF230.hex` – for STK600/ATxmega256A3 and RZ600 radio stick with RF230 onboard, acting as Router
- `WSNDemoApp_EndDev_RF230.hex` – for STK600/ATxmega256A3 and RZ600 radio stick with RF230 onboard, acting as End Device
- `WSNDemoApp_Coord_RF212US.hex` – for STK600/ATxmega256A3 and RZ600 radio stick with RF212 onboard, acting as Coordinator
- `WSNDemoApp_Router_RF212US.hex` – for STK600/ATxmega256A3 and RZ600 radio stick with RF212 onboard, acting as Router
- `WSNDemoApp_EndDev_RF212US.hex` – for STK600/ATxmega256A3 and RZ600 radio stick with RF212 onboard, acting as End Device
- `WSNDemoApp_Coord_RF231.hex` – for STK600/ATxmega256A3 and RZ600 radio stick with RF231 onboard, acting as Coordinator
- `WSNDemoApp_Router_RF231.hex` – for STK600/ATxmega256A3 and RZ600 radio stick with RF231 onboard, acting as Router
- `WSNDemoApp_EndDev_RF231.hex` – for STK600/ATxmega256A3 and RZ600 radio stick with RF231 onboard, acting as End Device

Note: Default images are pre-configured to use Extended PAN ID `0xAAAAAAAAAAAAAAAA` and operate on channel `0x0F` (for RF231 and RF230 radios) or channel `0x01` and channel page 0 (for RF212 radio).

12.4 Running WSNDemo

12.4.1 Starting WSNDemo

To run WSN Demo application, proceed as follows:

- Setup the hardware as described in Section 12.1.2. Make sure to connect LEDs and UART as described.
- Install BitCloud SDK as described in Section 12.1.4.
- Program devices as described in section 12.2.
- Attach STK600 #1 (Coordinator) RS232 connector to PC COM port.
- Run WSN Monitor (see Section 5.5).
- Power ON the rest of the nodes.

12.4.2 Monitoring WSNDemo Activity

Network activity can be monitored in two ways:

- Observing color LEDs of STK600 boards (see the table below);
- Monitoring the network topology through the WSN Monitor installed on PC.

Table 12-5. LED indication for the STK600 boards used in WSNDemo

Node State	LED0 State	LED1 State	LED2 State
Searching for network	Blinking	OFF	OFF
Joined to network	ON		
+ receiving data		Blinking	

Node State	LED0 State	LED1 State	LED2 State
+ sending data to UART (coordinator only)			Blinking
Sleeping (end device only)	OFF	OFF	OFF

12.4.3 Demonstrating OTA Upgrade functionality

OTA upgrade functionality of BitCloud can be demonstrated using XMEGA platform by using a Serial DataFlash™ device found on STK600 board. Once DataFlash™ is connected to ATxmega256A3 as defined in Section 12.1.2, the user should configure and install devices as follows:

1. Load WSN Demo application configured and compiled with `APP_USE_OTAU` defined as 1 under project in `iarConfiguration.h` file.
    a. Program serial bootloader bootstrap `bootloaderOTAU_ATXmega256A3.hex` or `bootloaderOTAU_ATXmega256D3.hex` located in `<SDK-Root>\Bootloader` folder of SDK according to platform specific instructions.
    b. Application image should be converted to `*.srec` format and installed using serial bootloader interface as described in Section 5.5.3.
    c. Device is able to act as OTA client as defined in [29].
2. Program another device with Runner application available in `<SDK-Root>\Evaluation Tools\Runner\` directory in SDK.
    b. Runner node acts as OTA server as defined in [29].

Once the images are programmed and WSNDemo devices are joined to the network follow instructions given in Section 5.5.3 to update firmware over the air.

12.5 Reserved Hardware Resources

Table 12-6. Hardware resources reserved by the stack on ATxmega256A3

Resource	Description
Processor main clock	16MHz from internal 32MHz RC-oscillator
Asynchronous clock	1kHz from 32kHz ultra low power internal oscillator
SPIC (Port C)	Radio interface
ATxmega ports PC0, PC2, PC3, PC4, PC5, PC6, PC7	Radio interface
RTC	Asynchronous timer
Timer/Counter C1	Radio interface and system timer
PORTC INT0	Radio interface
EEPROM	Storage for user settings accessible via Persistent Data Server
PD4..PD7	External DataFlash™, when OTAU functionality is used

13 Appendix A-6: AT91SAM7X-EK Specifics

13.1 Getting Started

13.1.1 Required Hardware

Before installing and using the BitCloud SDK make sure that all necessary hardware is available for the kit you would like to use:

- Two or more AT91SAM7X-EKs. For each, additionally:
    - RZ600 radio board with 10-pin squid cable
- AT91SAM-ICE JTAG emulator

13.1.2 Hardware Setup

Please refer to [24] for setup instructions.

Table 13-1. SAM7X-EK to RZ600 radio board pin mapping

SAM7X-EK J16 pin	Radio board pin	Pin name
A10	1	Reset
N/A	2	Misc
A31	3	Interrupt
A9	4	Sleep transmit
A15	5	Chip select
A18	6	MOSI
A17	7	MISO
A19	8	SCK
C32	9	GND
C31	10	VCC

13.1.3 System Requirements

Before using the SDK, please ensure that the following system requirements are met by your PC and development environment.

Table 13-2. System requirements for AT91SAM7X-EK

Parameter	Value	Note
CPU	Intel Pentium III or higher, 800MHz	
RAM	128MB	
Free space on hard disk	50MB	
JTAG emulator	AT91SAM-ICE emulator with cable	Required to upload and debug firmware onto the boards through JTAG (see Section 0).
Operating system	Windows 2000/XP	

Parameter	Value	Note
IDE	Eclipse IDE for C/C++ , YAGARTO toolchain (GCC 4.5.1 [(1)]) and AT91-ISP v1.12 OR IAR Embedded Workbench ARM 5.41.0 (with IAR C/C++ Compiler for AVR 5.41.0.51741 [(1)])	Required to develop applications using API (see Section 6.2) and to upload firmware images through JTAG (see Section 0), and
Java Virtual Machine	Java Runtime Environment (JRE) 5 Update 8, or later	Required to run WSNMonitor application

Notes: 1,2 Users are strongly encouraged to use the specified version of YAGARTO and/or IAR toolchains. Other versions are not supported and may not work.

13.1.4 Installing the SDK

Proceed with the following installation instructions.

1. Download the archive to your PC and unpack it into an empty folder. As a result, the following SDK folders and files will be created.

Table 13-3. The SDK file structure

Directory/File	Description
`<SDK-Root>\Documentation`	Documentation on BitCloud software
`<SDK-Root>\Evaluation Tools\WSNDemo (Embedded)`	Ready-to-use image files for evaluating WSNDemo. Refer to section 13.3 for the description of the images.
`<SDK-Root>\Evaluation Tools\WSNDemo (WSN Monitor)\WSNMonitorSetup.exe`	WSN Monitor installer
`<SDK-Root>\BitCloud\Components`	Header files for BitCloud Stack
`<SDK-Root>\BitCloud\Components\BSP\`	Source, header and library files for BitCloud BSP
`<SDK-Root>\BitCloud\lib`	Library files for BitCloud Stack
`<SDK-Root>\Sample Applications\`	Source codes for sample applications
`<SDK-Root>\Third Party Software\6119.inf`	USB to Serial Converter driver

2. Install selected IDE
   a. For Eclipse IDE and YAGARTO:
      i. Install Eclipse IDE for C/C++ [22], if not already installed on your PC.
      ii. Install YAGARTO ARM cross-compiler toolchain [23], if not already installed on your PC. Be sure to install only the supported version of YAGARTO toolchain as specified in Table 13-2.
   b. For IAR Embedded Workbench ARM:

i. Install IAR Embedded Workbench for ARM [21], if not already installed on your PC.

ii. Add a Windows® environment variable called IAR_ARM_HOME and set its value to the installation directory of IAR Embedded Workbench (for default installation it is "`C:\Program Files\IAR Systems\Embedded Workbench 5.4_0`"). To do this go to `Control Panel > System > Advanced > Environment Variables`, click `New` below `System variables` list and enter `Variable Name` and `Variable Value`. This step is required if you plan to build embedded images using IAR Embedded Workbench from command line.

3. Install AT91-ISP [25], if not already installed on your PC.
4. Install USB to Serial Converter driver. To install the driver, please attach the AT91SAM7X-EK device to your PC and wait for Windows to request for a specific driver for the device. If the device already has an assigned driver, or Windows assigned driver to it automatically, go to Start/Control Panel/System/Hardware/Device Manager, double-click the device and select "Update Driver…". In any case, please choose the "Install from a list or specific location" option and point to 6119.inf provided with this SDK. Please refer to section 4.9.1 of [8] for further details and basic troubleshooting options.

- Download and install Java Runtime Environment [12], if not already installed on your PC.

13.2 Programming the Boards

13.2.1 Setting Parameters

For proper operation all nodes in ZigBee network shall have unique MAC address values. On SAM7X platform a unique `CS_UID` parameter must be specified for each device in the application configuration (see details in Section 6.2.1), and then the application image must be built separately for each board.

13.2.2 Programming

AT91SAM-ICE JTAG emulator and SAM Boot Assistant [26] (available in AT91-ISP package) shall be used for programming.

Connect AT91SAM7X-EK board via SAM-ICE JTAG emulator to PC. After that run SAM-BA on the PC and choose \jlink\ARMX as connection type and AT91SAM7X-EK as target board. In opened window select Flash memory tab and provide path to application firmware image in `.bin` format in "Send File Name" field. Keep default memory settings and press "Send file button". After programming the image reset the AT91SAM7X-EK board. For details about SAM-BA configuration and usage please refer to SAM-BA User Guide [26].

Note: BitCloud stack and applications can be configured to store stack and application parameters in non-volatile memory (typically, EEPROM). This functionality cannot be demonstrated with stock SAM7X-EK kit as there is no external EEPROM on these boards. It's also not enabled in reference applications and pre-built binaries provided with SDK.

13.3 Pre-Built Images

The SDK comes with ready-to-use binary images of WSN Demo application. There is a set of images for different roles and pre-configured MAC addresses, so they can be used to setup a small ZigBee network right away. The pre-built Coordinator image is configured to communicate with PC via USB.

- `WSNDemoApp_Coord_RF230.bin` – for AT91SAM7X-EK and RF230-based RZ600 radio stick, acting as Coordinator
- `WSNDemoApp_Router_RF230.bin` – for AT91SAM7X-EK and RF230-based RZ600 radio stick, acting as Router
- `WSNDemoApp_EndDev_RF230.bin` – for AT91SAM7X-EK and RF230-based RZ600 radio stick, acting as End-Node
- `WSNDemoApp_Coord_RF212US.bin` – for AT91SAM7X-EK and RF212-based RZ600 radio stick, acting as Coordinator
- `WSNDemoApp_Router_RF212US.bin` – for AT91SAM7X-EK and RF212-based RZ600 radio stick, acting as Router
- `WSNDemoApp_EndDev_RF212US.bin` – for AT91SAM7X-EK and RF212-based RZ600 radio stick, acting as End-Node
- `WSNDemoApp_Coord_RF231.bin` – for AT91SAM7X-EK and RF231-based RZ600 radio stick, acting as Coordinator
- `WSNDemoApp_Router_RF231.bin` – for AT91SAM7X-EK and RF231-based RZ600 radio stick, acting as Router
- `WSNDemoApp_EndDev_RF231.bin` – for AT91SAM7X-EK and RF231-based RZ600 radio stick acting as End-Node

Note: Default images are pre-configured to use Extended PAN ID `0xAAAAAAAAAAAAAAAA` and operate on channel `0x0F` (for RF231 and RF230 radios) or channel `0x01` and channel page 0 (for RF212 radio).

13.4 Running WSNDemo

13.4.1 Starting WSNDemo

To run WSN Demo application, proceed as follows:

1. Setup the hardware as described in Section 13.1.2.
2. Install BitCloud SDK as described in Section 13.1.4.
3. Program devices as described in section 13.2.
4. Connect AT91SAM7X-EK #1 (Coordinator) to PC USB port.
5. Run WSN Monitor (see Section 5.5).
6. Power ON the rest of the nodes.

13.4.2 Monitoring WSNDemo Activity

Network activity can be monitored in two ways:

- Observing color LEDs of AT91SAM7X-EK boards (see the table below);
- Monitoring network topology through the WSN Monitor installed on PC.

Table 13-4. LED indication for AT91SAM7X-EK boards used in WSNDemo

Node State	LED1 (Red)	LED2 (Yellow)	LED3 (Green)
Searching for network	Blinking	OFF	OFF
Joined to network	ON		
+ receiving data		Blinking	
+ sending data to UART (coordinator only)			Blinking

13.5 Reserved Hardware Resources

Table 13-5. Hardware resources reserved by the stack on AT91SAM7X256

Resource	Description
SPI0	Radio interface
ARM ports PA8, PA9, PA14, PA16, PA17, PA18, PA30	Radio interface
Timer2	Microseconds timer
Timer0	System timer
External IRQ0	Radio interface
SPI1, PA21, PA22, PA23, PA24	For external EEPROM

14 Appendix A-7: SAM3S-EK Specifics

14.1 Getting Started

14.1.1 Required Hardware

Before installing and using the BitCloud SDK make sure that all necessary hardware is available for the kit you would like to use:

- Two or more SAM3S-EK boards. For each, additionally:
    - RZ600 radio board featuring RF231 radio transceiver
- AT91SAM-ICE JTAG emulator

14.1.2 Hardware Setup

Connect RZ600 radio board transceiver to J16/ZigBee connector present on SAM3S-EK board.

For other HW setup instructions please refer to [28].

14.1.3 System Requirements

Before using the SDK, please ensure that the following system requirements are met by your PC and development environment.

Table 14-1. System requirements for SAM3S-EK

Parameter	Value	Note
CPU	Intel Pentium III or higher, 800MHz	
RAM	128MB	
Free space on hard disk	50MB	
JTAG emulator	AT91SAM-ICE emulator with cable	Required to upload and debug firmware onto the boards through JTAG (see Section 0).
Operating system	Windows 2000/XP	
IDE	IAR Embedded Workbench ARM 5.4 (with IAR C/C++ Compiler for AVR 5.41.0 (1))	Required to develop applications using API (see Section 6.2) and to upload firmware images through JTAG (see Section 0), and
Java Virtual Machine	Java Runtime Environment (JRE) 5 Update 8, or later	Required to run WSNMonitor application

Notes: 1 Users are strongly encouraged to use the specified version of IAR toolchain. Other versions are not supported and may not work.

14.1.4 Installing the SDK

Proceed with the following installation instructions.

1. Download the archive to your PC and unpack it into an empty folder. As a result, the following SDK folders and files will be created.

Table 14-2. The SDK file structure

Directory/File	Description
`<SDK-Root>\Documentation`	Documentation on BitCloud software
`<SDK-Root>\Evaluation Tools\WSNDemo (Embedded)`	Ready-to-use image files for evaluating WSNDemo. Refer to section 13.3 for the description of the images.
`<SDK-Root>\Evaluation Tools\WSNDemo (WSN Monitor)\WSNMonitorSetup.exe`	WSN Monitor installer
`<SDK-Root>\BitCloud\Components`	Header files for BitCloud Stack
`<SDK-Root>\BitCloud\Components\BSP\`	Source, header and library files for BitCloud BSP
`<SDK-Root>\BitCloud\lib`	Library files for BitCloud Stack
`<SDK-Root>\Applications/`	Source codes for sample applications

2. Install
    a. For IAR Embedded Workbench ARM:
        i. Install IAR Embedded Workbench for ARM [21], if not already installed on your PC.
        ii. Add a Windows® environment variable called IAR_ARM_HOME and set its value to the installation directory of IAR Embedded Workbench (for default installation it is "`C:\Program Files\IAR Systems\Embedded Workbench 5.4_0`"). To do this go to `Control Panel > System > Advanced > Environment Variables`, click `New` below `System variables` list and enter `Variable Name` and `Variable Value`. This step is required if you plan to build embedded images using IAR Embedded Workbench from command line.
3. Install AT91-ISP [25], if not already installed on your PC.
4. Download and install Java Runtime Environment [12], if not already installed on your PC.

14.2 Programming the Boards

14.2.1 Setting Parameters

For proper operation all nodes in ZigBee network shall have unique MAC address values. On SAM3S platform a unique `CS_UID` parameter must be specified for each device in the application configuration (see details in Section 6.2.1), and then the application image must be built separately for each board.

14.2.2 Programming

AT91SAM-ICE JTAG emulator and SAM Boot Assistant [26] (available in AT91-ISP package) shall be used for programming.

Connect SAM3S-EK board via SAM-ICE JTAG emulator to PC. After that run SAM-BA on the PC and choose \jlink\ARMX as connection type and SAM3S-EK as target board. In opened window select Flash memory tab and provide path to application firmware image of `.bin` format in “Send File Name” field. Keep default memory settings and press “Send file button”. After programming the image reset the SAM3S-EK board.

For details about SAM-BA configuration and usage please refer to SAM-BA User Guide [26].

Note: BitCloud stack and applications can be configured to store stack and application parameters in non-volatile memory (typically, EEPROM). This functionality cannot be demonstrated with stock SAM3S-EK kit as there is no external EEPROM on these boards. It’s also not enabled in reference applications and pre-built binaries provided with SDK.

14.3 Pre-Built Images

The SDK comes with ready-to-use binary images of WSN Demo application. There is a set of images for different roles with different pre-configured MAC addresses so they can be used to setup a small ZigBee network right away.

- `WSNDemoApp_Coord_RF231.bin` – for SAM3S-EK and RZ600 radio stick with RF231 on board, acting as Coordinator
- `WSNDemoApp_Router_RF231.bin` – for SAM3S-EK and RZ600 radio stick with RF231 on board, acting as Router
- `WSNDemoApp_EndDev_RF231.bin` – for SAM3S-EK and RZ600 radio stick with RF231 on board, acting as End-Node
- `WSNDemoApp_Coord_RF212US.bin` – for SAM3S-EK and RZ600 radio stick with RF231 on board, acting as Coordinator
- `WSNDemoApp_Router_RF212US.bin` – for SAM3S-EK and RZ600 radio stick with RF231 on board, acting as Router
- `WSNDemoApp_EndDev_RF212US.bin` – for SAM3S-EK and RZ600 radio stick with RF231 on board, acting as End-Node
- `WSNDemoApp_Coord_RF230.bin` – for SAM3S-EK and RZ600 radio stick with RF230 on board, acting as Coordinator
- `WSNDemoApp_Router_RF230.bin` – for SAM3S-EK and RZ600 radio stick with RF230 on board, acting as Router
- `WSNDemoApp_EndDev_RF230.bin` – for SAM3S-EK and RZ600 radio stick with RF230 on board, acting as End-Node

Note: Default images are pre-configured to use Extended PAN ID `0xAAAAAAAAAAAAAAAA` and operate on channel `0x0F` (for RF231 and RF230 radios) or channel `0x01` and channel page 0 (for RF212 radio).

14.4 Running WSNDemo

14.4.1 Starting WSNDemo

To run WSN Demo application, proceed as follows:

1. Setup the hardware as described in Section 14.1.2.
2. Install BitCloud SDK as described in Section 14.1.4.
3. Program devices as described in section 14.2.
4. Connect SAM3S-EK programmed as Coordinator to PC COM port.
5. Run WSN Monitor (see Section 5.5).
6. Power ON the rest of the nodes.

14.4.2 Monitoring WSNDemo Activity

Network activity can be monitored in two ways:

- Observing color LEDs of SAM3S-EK boards (see the table below);
- Monitoring network topology information through the WSN Monitor installed on PC.

Table 14-3. LED indication for SAM3S-EK boards used in WSNDemo

Node State	LED D2 (Blue)	LED D3 (Yellow)	LED D4 (Red)
Searching for network	Blinking	OFF	OFF
Joined to network	ON		
+ receiving data		Blinking	
+ sending data to UART (coordinator only)			Blinking

14.5 Reserved Hardware Resources

Table 14-4. Hardware resources reserved by the stack on ATSAM3S4C

Resource	Description
SPI	Radio interface
MCU ports PB3, PA15, PA17, PA18, PA12, PA13, PA14	Radio interface
Timer0, channel0	System timer
Port A interrupt	Radio interface

15 Appendix B-1: Over-the-Air Protocol

This appendix describes the protocol used by the WSNDemo sample application. The description includes the format of the messages exchanged over the air between the connected nodes. The protocol description allows non-standard nodes (e.g. those using 3rd party sensors not available on the standard evaluation boards and kits) to transfer sensor readings and have them visualized in the same WSN Monitor application.

15.1 Message Format

End-devices and routers send messages to the coordinator using the following format.

Table 15-1. WSNDemo message format

Field Name	Length	Description
Message Type	1 byte	Type of the messages. Must be 0x01 (0x01 is the only supported message type for the current revision of WSNDemo)
Node type	1 byte	Type of the sending node: 0 – coordinator 1 – router 2 – end-device
IEEE address	8 bytes	IEEE address of the sending node
Short address	2 bytes	Short address of the sending node
Version	4 bytes	Version of WSNDemo application protocol used by the sending node. Currently set to 0x01010100.
Channel mask	4 bytes	Channel mask set on the sending node
PANID	2 bytes	PAN ID of the network to which the sending node is attached
Channel	1 byte	The channel on which the sending node operates
Parent address	2 bytes	Short address of the parent node
LQI	1 byte	LQI observed by the node that sends this message
RSSI	1 byte	RSSI observed by the node that sends this message
<Additional fields>	<Variable>	Optional additional fields, see description below in section 15.2

15.2 Additional fields

The message may contain zero, one, or more additional fields that follow the mandatory fixed-width fields described in the table above. The order of the additional fields is not fixed. The size of the additional fields may vary – each field contains a sub-field defining its size. Below is the description of the general format of an additional field.

Table 15-2. Additional field format

Sub-Field Name	Length	Description
Field Type	1 byte	Type of the additional field. The possible values are listed below.

Sub-Field Name	Length	Description
Field Size	1 byte	Size of the Field Data in bytes. Note: this size does not include the Field Type and Field Size sub-fields
Field Data	<Variable>	The data depend on the Field Type, the size of the data is provided by the Field Size

The following types of additional fields are defined:

Table 15-3. Additional field types

Field Type	Description
0x01	Sensors data for board type 1. Used for ATAVRRZRAVEN kit boards and MeshBean boards.
0x20	Node name.

Please note that in the current version of WSNDemo devices send additional fields of type 0x01 (sensors readings for boards of type 1) only. Unrecognized additional fields are discarded by WSN Monitor application. The Field Data format for different field types are described in the following tables.

Table 15-4. Field Data for type 0x01: Sensors data for board type 1

Offset	Length	Data Type	Description
0	4 bytes	Unsigned int	Battery status reading
4	4 bytes	Unsigned int	Temperature sensor reading
8	4 bytes	Unsigned int	Light sensor reading

Table 15-5. Field Data for type 0x20: Node name

Offset	Length	Description
0	<Variable>	Zero-terminated ASCII string

16 Appendix B-2: Serial Protocol

This appendix describes the protocol and message format used over the serial connection between the network coordinator and the WSN Monitor application running on the PC. The messages sent on the serial connection are basically the messages defined in section 8.1 wrapped as defined below:

Table 16-1. Serial message format

Offset	Length	Description
0	2 bytes	Start sequence: 0x10 0x02
2	N bytes	Variable-length payload: the message received from end-node or router or generated by the coordinator, in the format described in section 8 All 0x10 bytes in this payload are duplicated to avoid confusion with Start sequence or End sequence
N+2	2 bytes	End sequence: 0x10 0x03
N+4	1 byte	Checksum: Sum of the bytes [0..N+3] mod 256

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