AN997: ETHERNET TO WI-FI BRIDGE MODE
WF121 WI-FI MODULE APPLICATION NOTE
Tuesday, 28 January 2014
Version 1.2
## VERSION HISTORY

<table>
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<th>Version</th>
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<td>1.0</td>
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</table>
TABLE OF CONTENTS

1 Introduction .................................................................................................................................................. 5
2 Introduction to the Bluegiga Wi-Fi Software ............................................................................................. 6
  2.1 The Bluegiga Wi-Fi Stack ..................................................................................................................... 6
  2.2 The Bluegiga Wi-Fi SDK ..................................................................................................................... 6
3 Implementing Ethernet to Wi-Fi Bridge ........................................................................................................ 8
  3.1 Creating a project ................................................................................................................................ 8
  3.2 Hardware configuration ....................................................................................................................... 9
  3.3 The BGScript Code ........................................................................................................................... 10
    3.3.1 Catching System Boot .................................................................................................................... 10
    3.3.2 Scanning for available networks and starting the Wi-Fi AP mode .................................................. 10
    3.3.3 Connecting to a Wi-Fi Access Point and starting the Ethernet bridge mode .................................. 11
4 Compiling the Firmware ............................................................................................................................. 12
5 Installing the Firmware .............................................................................................................................. 14
  5.1 Using PICkit 3 ................................................................................................................................... 14
  5.2 Using DFU over UART or USB ......................................................................................................... 15
6 Testing the Ethernet Bridge ....................................................................................................................... 16
  6.1 Test Setup ......................................................................................................................................... 16
  6.2 Enabling the Ethernet bridge mode .................................................................................................. 16
7 Contact Information ................................................................................................................................... 18
1 Introduction

This application note describes the configuration and usage of Ethernet connectivity in the Bluegiga WF121 Wi-Fi module. The Ethernet, in the WF121, can be used in two different modes either as a Wi-Fi to Ethernet Bridge or alternatively it can be used to access the IP network instead of Wi-Fi. This application note will focus on how to configure and use the Ethernet to Wi-Fi Bridge mode.

This document follows the WF121 Software Development Kit’s (SDK) Ethernet-example.

![Figure 1: Illustration of Wi-Fi to Ethernet Bridge](image)

The Ethernet to Wi-Fi Bridge mode can be used to bring wireless connectivity to devices where there is only Ethernet interface available. The Bridge will appear as transparent data pipe, streaming data from Wi-Fi network to the Ethernet device and vice versa. In this example, the setup is made easy with running an HTTP-server on the module, which can be accessed with the Ethernet connection and a web browser. After the Wi-Fi network has been configured the WF121 will act as a Bridge and the Wi-Fi router only sees the end device (i.e., the device connected to WF121 over Ethernet) and assigns an IP address to the end device.

This document will describe the following components:
- Short description of the Bluegiga Wi-Fi Software architecture
- The example’s configurations for both Software and Hardware
- A walkthrough of the BGScript implementing example’s functionality
- Compiling the Firmware
- Installing the Firmware
- Step by step instructions of example’s usage
2 Introduction to the Bluegiga Wi-Fi Software

The Bluegiga Wi-Fi Software enables developers to quickly and easily develop Wi-Fi applications without in-depth knowledge of the Wi-Fi technology. The Wi-Fi Software consists of two parts:

- The Bluegiga Wi-Fi Software
- The Bluegiga Wi-Fi Software Development Kit (SDK)

2.1 The Bluegiga Wi-Fi Stack

The Bluegiga Wi-Fi Stack is an embedded 802.11 MAC and IPv4 stack targeted for Bluegiga's WF121 Wi-Fi module. The Wi-Fi software implements full 802.11 functionality, Station and Access Point modes, WPA2, WPA and WEP and WPS security and various IP based protocols such as TCP, UDP, DHCP, DNS, ICMP and HTTP server.

The Bluegiga Wi-Fi Stack provides powerful, low overhead and easy-to-use Bluegiga BGAPI™ binary API that can be used over UART, USB or SPI interfaces and it provides functions such as such as Access Point discovery, Access Point association, encryption, and connection establishment. The Wi-Fi Stack also supports the 802.11 access point mode and implements an embedded HTTP server for the easy configuration and offers direct connections to phones, tablets and PC's. To simplify the software development the Bluegiga Wi-Fi software also includes a Bluegiga BGLib™ C-library that implements the BGAPI protocol parser for various embedded systems.

For standalone applications the Bluegiga Wi-Fi Software also provides a simple BGScript™ scripting language and VM environment, which enables the users to write simple applications for the WF121 Wi-Fi module. This enables lower cost and smaller designs to be made as there is no need to use an external MCU.

2.2 The Bluegiga Wi-Fi SDK

The Bluegiga Wi-Fi SDK is a software development kit, which enables the device and software vendors to develop products on top of the Bluegiga's Wi-Fi hardware and software.

The Wi-Fi SDK supports multiple development models and the software developers can decide whether the application software runs on a separate host (a low power MCU) or whether they want to make fully standalone devices and execute their code on the MCU embedded in the Bluegiga Wi-Fi modules. The SDK also contains documentation, tools for compiling the firmware, installing it into the hardware and lot of example applications speeding up the development process.

Fully standalone applications can be developed using a simple scripting language called BGScript™. Several examples are also offered as a part of the Wi-Fi SDK in order to easily develop Wi-Fi compatible end products. These examples contain for example embedded HTTP server, WPS and TCP to Serial applications.
The Bluegiga Wi-Fi Software architecture is illustrated above and it consists of the following components:

- The Bluegiga Wi-Fi stack implementing the 802.11, 802.2, IPv4 and higher level protocols
- **BGAPI** APIs that enable the software developers to interface to the Wi-Fi Stack
- **BGLib** lightweight host library which implements the BGAPI binary protocol and parser and is target for applications where separate host processor is used to interface to the Wi-Fi modules over UART, USB or SPI.
- **BGScript** Virtual Machine (VM) and scripting language which enable application code to be developed and executed directly on the Bluegiga Wi-Fi hardware
3 Implementing Ethernet to Wi-Fi Bridge

3.1 Creating a project

The implementation is started by first creating a WF121 project file (project.xml), which defines the resources use by the project and the firmware output file.

```xml
<?xml version="1.0" encoding="UTF-8" ?>
<project>
  
  <hardware in="hardware.xml" />

  <scripting>
    <script in="wifi.bgs"/>
  </scripting>

  <software>
    <binary in="fw/wifi_http_serv.jug" />
  </software>

  <image out="WF121_ETHBridge.dfu" out_hex="WF121_ETHBridge.hex" />

  <files>
    <file path="404.html"/>
    <file path="main.html"/>
    <file path="client.html"/>
    <file path="index.html"/>
    <file path="logo.gif"/>
    <file path="style.css"/>
  </files>

</project>
```

Figure 3: WF121 Project file

- **<hardware>** Defines the XML-file or XML tags containing the hardware configuration.
- **<script>** Defines the BGScript-file which contains the BGScript application code.
- **<binary>** Defines the WF121 firmware image used in the project. With the Ethernet Bridge example a software profile called wifi_http_serv must be used since the example also implements HTTP server functionality which is used for configuration.
  
  For details of different options see the software profiles chapter in the WF121 configuration guide.
- **<image>** Defines the DFU and HEX firmware output files
- **<files>** Defines the HTML, CSS and GIF files used by the embedded HTTP server
3.2 Hardware configuration

The `project.xml` file contains the hardware configuration for WF121 Wi-Fi Module. It describes which interfaces and functions are in used and their properties.

```xml
<hardware>
  <uart channel="1" baud="5600000" api="true" handshake="True" />
  <ethernet enable="1"/>
  <sleep interrupts="1"/>
</hardware>
```

**Figure 4: Hardware configuration for WF121 Wi-Fi Module**

- `<uart>`: This setting configures the UART interface. The first UART tag enables the UART2 interface with 115200bps baud rate and hardware flow control enabled. The UART provides access to the BGAPI protocol.
- `<ethernet>`: This setting enables the Ethernet (RMII) interface on the WF121 module.
- `<sleep>`: This setting will enable INT0 (pin 38) wake-up interrupt

The illustration below shows the hardware block diagram on the WF121 development kit and how the development kit should be connected to a PC in order to try out this application.

**Figure 5: Block diagram of the hardware setup**

On the WF121 development kit the following configurations are also needed:

- Switch the Ethernet switch (labelled SW1) to **ON** position

**Note:**

When Ethernet port is used with the WF121 Wi-Fi Module - and this applies to all Ethernet applications - the following pins / ports of WF121 cannot be used for any other purpose.

- RD1, RD7, RD8, RD9, RB15, RD[port] and RF0 and RF1.
3.3 The BGScript Code

The BGScript application is used to implement the actual application logic controlling the Wi-Fi to Ethernet bridge application. This section of the document briefly walks you through the most important sections of the BGScript application and explains what the script code does.

3.3.1 Catching System Boot

The system boot event is the starting point for all BGScript applications and the event is generated always when the WF121 Wi-Fi module is power on or reset.

In this application the system boot code will perform the following steps:

1. Necessary variables are initialized
2. The last known operating mode is read from the PS keys (parameters stored of flash), in case the application has been used before and the operating mode has been stored to the flash.
   a. The operating mode function is called to set the correct operating mode
3. The Wi-Fi radio is turned on

```plaintext
***Module is powered***

event system_boot(major, minor, patch, build, bootloader_version, tcpip_version, hw)
# Initialize variables
reconnect_count = 0
operating_mode = MODE_AP
ps_label_scan_result = FLASH_PS_KEY_SCAN_RESULT_START
ap_channel = 1
ap_security = 0
ap_ssid_len = 6
ap_ssid(0:ap_ssid_len) = "Bg_eth"
ap_pw_len = 0
ap_pw(0:ap_pw_len) = ""
wifi_on = 2

#initialize LED port
call hardware_io_port_config_direction(LED_PORT, ETH_LED, $0000)
call hardware_io_port_config_direction(LED_PORT, AP_LED, $0000)
call hardware_io_port_config_direction(LED_PORT, STA_LED, $0000)

#if read and set operating mode
call flash_ps_load(FLASH_PS_KEY_MODULE_SERVICE) (result, value_len, value_data(0:value_len))
if result = 0
  operating_mode = value_data(0:value_len)
end if
call sme_set_operating_mode(operating_mode)
#enable Wi-Fi

call sme_wifi_on()
end
```

Figure 6: System boot event listener

3.3.2 Scanning for available networks and starting the Wi-Fi AP mode

When the application is started the very first time (or after factory reset) it BGScript code will initialize a Wi-Fi Access Point scan in order to discovery nearby networks, store the results into PS keys and finally turn the WF121 Wi-Fi Module into an Access Point mode to initialize the stack.

- **sme_wifi_is_on()** event listener initiates the Access Point scan
When the scan is ready the event `sme_scanned()` is generated, which on the other hand initiates sorting of the scan results based on RSSI.

Scan results are then stored into PS-keys for future usage by `sme_scan_sort_result` event listener.

Finally when sorting has been finished the WF121 is turned into Wi-Fi mode by the `sme_scan_sort_finished` event listener.

The application can be configured either over a wireless link or over the Ethernet connection. The end user can connect the WF121 Wi-Fi Module Access Point, if Ethernet cable is not connected, for example from a smart phone or a PC and access the built in HTTP server and configure the Wi-Fi network WF121 is supposed to connect to by selecting the SSID and security configuration of the network. When the Ethernet cable is connected, the HTTP server has to be accessed over that connection.

- **start_ap_mode** procedure starts the Wi-Fi AP mode and loads the previous (or factory default) settings from the PS-keys such as the SSID, password DHCP and DNS server configurations. Also the Ethernet bridging is disabled at this state of the application.

- When the AP mode has been started an `sme_ap_mode_started` event is generated, which finally enables the HTTP and DHCP servers.

After these steps have been completed by the BGScript application the device should be visible as a Wi-Fi Access Point, if the Ethernet cable is not connected, and can be connected from a smart phone, table or PC in order to device via the HTTP server.

### 3.3.3 Connecting to a Wi-Fi Access Point and starting the Ethernet bridge mode

Once the end user has configured the WF121 Wi-Fi module via the HTTP server and selected the Wi-Fi network it needs to connect to the BGScript application performs the following steps:

- After reset and when Wi-Fi is turned on in the `sme_wifi_is_on` event handler the `start_sta_mode` procedure is called in order to start the Wi-Fi client (STA) mode and connect to a network.

- In the `start_sta_mode` procedure the DHCP client is enabled and the HTTP, DHCP and DNS servers are disabled. Also the settings of the Access Point that the WF121 is supposed to connect to are read from the PS keys.

- Finally `sme_connect_ssid` is called to begin the connection establishment, authentication and encryption procedures.

- If the connection is successful `sme_connected` event is generated and the Ethernet bridge mode is also started with command `ethernet_set_dataroute(ETH_TO_WIFI)`.

```plaintext
***Module is connected to AP***
eveme sme_connected |status, hw_interface, bssid|
  #set Ethernet in bridge mode
  call ethernet_set_dataroute(ETH_TO_WIFI)
  call hardware_io_port_write(LED_PORT, STA_LED, STA_LED)
end
```

**Figure 7: Starting Ethernet Bridge**

**Note:**
The status LEDs D4 and D5 state is changed to always ON when the bridging connection is successful. For other led states and functionality, please refer to the actual BGScript code.
4 Compiling the Firmware

The firmware is compiled with either the `bgbuild.exe`, this can for example be done from the Windows Command Line Prompt (`cmd.exe`), or the WF121 GUI's built-in compiler tool, please refer to Figure 10: Updating firmware via DFU Figure 10. The figure below shows how to compile the Ethernet example project with the BGBuild compiler.

![Figure 8: Screen capture of compiling the project with bgbuild.exe](image)

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Compiler output and explanations with the default configurations:

<table>
<thead>
<tr>
<th>Feature</th>
<th>Output</th>
<th>Explanation</th>
</tr>
</thead>
</table>
| uart:1  | high_speed : enabled  
baudrate : 5000000  
actual : 5000000  
error% : 0  
handshake : true  
BGAPI : true  
BRG : 0x1  
MODE : 0x8208 | Shows that UART2 is enabled at 5Mbps baud rate.  
RTS/CTS handshaking is enabled.  
BGAPI protocol is also ENABLED for UART2. |
| sleep   | wakeup int: 1  
wdt_wakeup: true | Enabled sleep settings |
| port: N | TRIS : ffff  
LAT : 0  
ODC : 0 | Shows the default configuration for Port N (B to G) and the setting for tri-state configuration bit mask, open drain configuration, and latched value for the port. |
| script  | compiler : C:/Bluegiga/wf121-1.2.x-YY/bin/script_compiler.exe  
script : wifi.bgs  
api : ../../api/wifiapi.xml  
stack : 512  
variables : 271 | Shows the directory where the bgbuild compiler is located.  
Shows the BGScript source code file. |
| HTTP server | FILE : 404.html  
size: 202  
FILE : main.html  
size: 280  
FILE : client.html  
size: 2744  
FILE : index.html  
size: 1173  
FILE : logo.gif  
size: 1011  
FILE : style.css  
size: 1255 | Shows the HTML pages and their sized that are compiled into the firmware. |
| Stack size | Memory Used :  
SW : 402104  
HW : 122  
USB : 0  
Script: 1035  
Files : 6760  
Free : 101979/512000(20%) | SW shows the flash usage (in B) of the firmware image.  
HW shows the size of the hardware configuration.  
USB shows the size of the USB interface descriptor.  
Script shows the size of BGScript.  
Files shows the size if the HTTP server files  
Free shows the total size of the software and how much space is left in the device. |

Table 1: Compiler output print explained
5 Installing the Firmware

The firmware can be installed either using the DFU protocol over UART or USB or via the debug interface using the Microchip PICkit3 tool and software.

5.1 Using PICkit 3

- As PICkit 3 will erase the full flash, please write down the MAC (IEEE) address of your device
- Download and install PICkit 3 software from Bluegiga web site
- Connect the PICkit 3 to the debug interface of your WF121 (header J11 on WF121 development kit) and connect the PICkit 3 to your PC via USB interface.
- Start PICkit 3 software
  - From Device Family select PIC32
  - From Device drop down list select model: PIC32MX695F512H
  - Verify the STATUS led on the PICkit 3 device turns green
  - From File select Import Hex
  - Choose the .hex file output by the BGBuild compiler
  - Press Write
- Wait for the programming to be successfully finalized

![Figure 9: Programming firmware using PICkit 3](image-url)
5.2 Using DFU over UART or USB

In order to install the firmware using DFU protocol, please do the following steps:

- Connect the WF121 Wi-Fi Module to PC via UART or USB, whichever is enabled on the firmware.
- Start WF121 GUI software
- Select the correct COM port and baud rate
  - Factory default settings: UART2 and 115200 baud rate
  - Verify the communication works for example by pressing Retrieve info button
- Go to Firmware update subpage
  - Press Boot in DFU mode button
    - A successful DFU mode is indicated with the event: wifi_evt_dfu_boot version: 4
  - Select the correct .DFU file using the Browse... button
  - Press Upload
- Make sure the firmware is uploaded correctly and the device boots normally
  - A successful DFU upload is indicated with event: wifi_rsp_dfu_flash_upload_finish result: 0
  - A successful boot is indicated with event: wifi_evt_system_boot

![Figure 10: Updating firmware via DFU](image)

Note:

DFU updates allow the change of hardware settings (in project.xml), so make sure you do not make unwanted changes to your hardware configuration when performing DFU updates.
6 Testing the Ethernet Bridge

This chapter briefly describes how to configure, using the HTTP server, the WF121 Wi-Fi Module to join an existing Wi-Fi network and start the Ethernet Bridge mode.

6.1 Test Setup

- DKWF121 development kit
  - Ethernet Bridge example firmware installed and not configured before
  - An Ethernet crossover cable available, but not connected
  - USB (USB-to-UART converter) connected to a PC to access the module with the WF121 GUI
- A Windows PC with a web browser
- A wireless network as a gateway to the Internet

6.2 Enabling the Ethernet bridge mode

1. Connect a USB cable between the PC and the WF121 development kit's USB-to-UART Converter.
2. Windows enumerates the two virtual COM ports, when the WF121 development kit is powered ON.
   You can verify this from the Windows’ device manager.
3. Start the WIFIGUI software delivered with the SDK and **Attach** up the higher of the two COM ports and using the 115200bps baud rate.
   a. Check the BGAPI communication works, for example by pressing **Retrieve Info** button and checking from the communication log that a proper response is received.
4. The WF121 module searches for wireless networks in the area. When the scan is finished and the WF121 module is in the Access Point mode, the RD6 led remain constantly on.
5. Connect the WF121 Access Point for example using your PC and navigate to the IP address `http://192.168.1.1` with your web browser. Make sure the PC is not connected to any other networks when you do this.
6. In the HTTP server the **Client**-page displays the discovered wireless networks from the area. Select a network you want to join to, or set the SSID of a known network to the corresponding text box. Next type in the password the network uses and press **Connect**. The WF121 Wi-Fi module will then connect the selected Access Point as a Wi-Fi client. Connect the crossover cable between the PC and the devkit. If the setup is successful, Ethernet bridging will be enabled and the RD4 and RD5 LEDs will turn ON.

**Note:**

The web browser might prompts that the connection to the HTTP server at 192.168.1.1 was lost and won’t be accessible any more. This is normal as the WF121 module is now in the Ethernet bridge mode.

7. To access the HTTP server again you can use the WIFIGUI application and reset the PS keys. You need to write the `FLASH_PS_KEY_MODULE_SERVICE` value to 2 and reset the WF121 Wi-Fi module and it will start again in the Wi-Fi Access Point mode. You can use WF121 GUI Firmware Update to erase the PS Keys as well.
Figure 11: The Client mode configuration page

Once the bridge mode has been enabled your PC should be connected to the same network as WF121 Wi-Fi module through the Wi-Fi to Ethernet Bridge. You can verify this for example from the Windows’ Network and Sharing Center.

Figure 12: Windows' Network and Sharing Center displaying a Local Area Connection
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