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AVNET

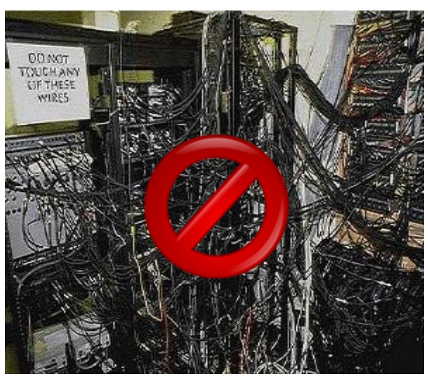
Peter Fenn

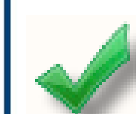
Adding Wireless Connectivity to Zynq Systems

Accelerating Your Success™

Wireless - More Important Than Ever!

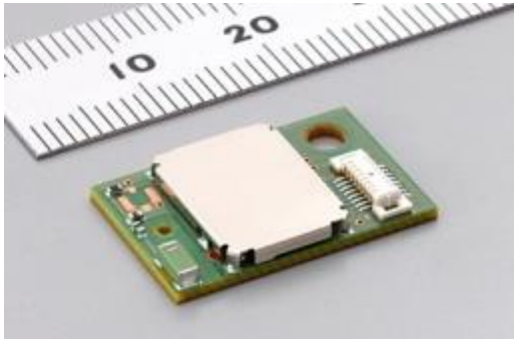
- Wireless is increasingly expected in new products!
- Internet of Things = “Billions of connected devices!”
- Wireless reduces cabling costs and installation effort for networks that are easy to expand and maintain.
- Wired connectivity not always practical (long cable runs, moving equipment, dangerous/harsh environments)





Wireless - Now Easier To Implement!

- Modules make it easier to add wireless to designs
- Combo devices support multiple wireless standards for different use cases, eg.
  - BLE for low-power sensor hub communication,
  - Wi-Fi for high throughput network communication
- Advantages to using wireless modules include:
  - risk mitigation, no need to be a wireless expert
  - reduced software effort / faster time-to-market
  - reduce or eliminate certification delays and expense



Wireless - Extends Zynq's Capabilities!

- "Future-Proof" Zynq designs for IoT and beyond
- Quality UI options via Wi-Fi to tablet or smartphone
- Robust, secure, high throughput network solution
- Lower overall Zynq system costs through reduced equipment-, installation and maintenance costs
- Wireless connected Zynq application prototyping possible with Zedboard and MicroZed platforms

ZedBoard

MicroZed™
FLEXIBILITY REDEFINED
MICROZED.ORG

picoZed™

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Course Objectives

- Gain expertise in module based wireless solutions and the hardware considerations when adding wireless to Zynq SoC based designs.

- Step through the process of adding a Wi-Fi module (via Pmod-based SDIO interface) to a Linux based Zynq design on MicroZed.

- Learn how to navigate popular wireless connectivity standards, the trade-offs and solutions and how to reduce overall risk and time-to-market.

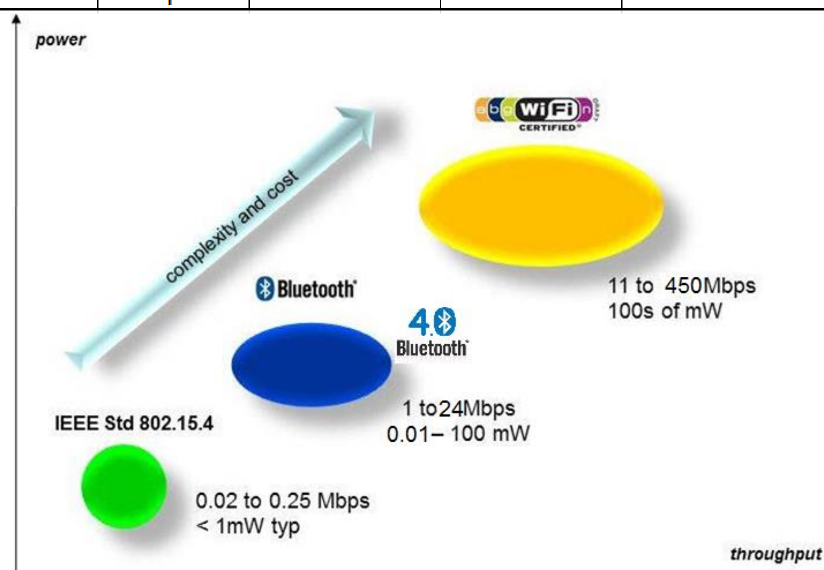
Agenda

- Choosing The Right Wireless Technology
- Considerations When Adding Wireless To Zynq
- Adding Wi-Fi To Linux Zynq Designs
- Example: Adding A Wi-Fi Module To MicroZed
- Wireless Modules Available From Avnet
- IoT - Ensure Your FPGA Design Stays Relevant!

Choosing The Right Wireless Technology For Your Needs

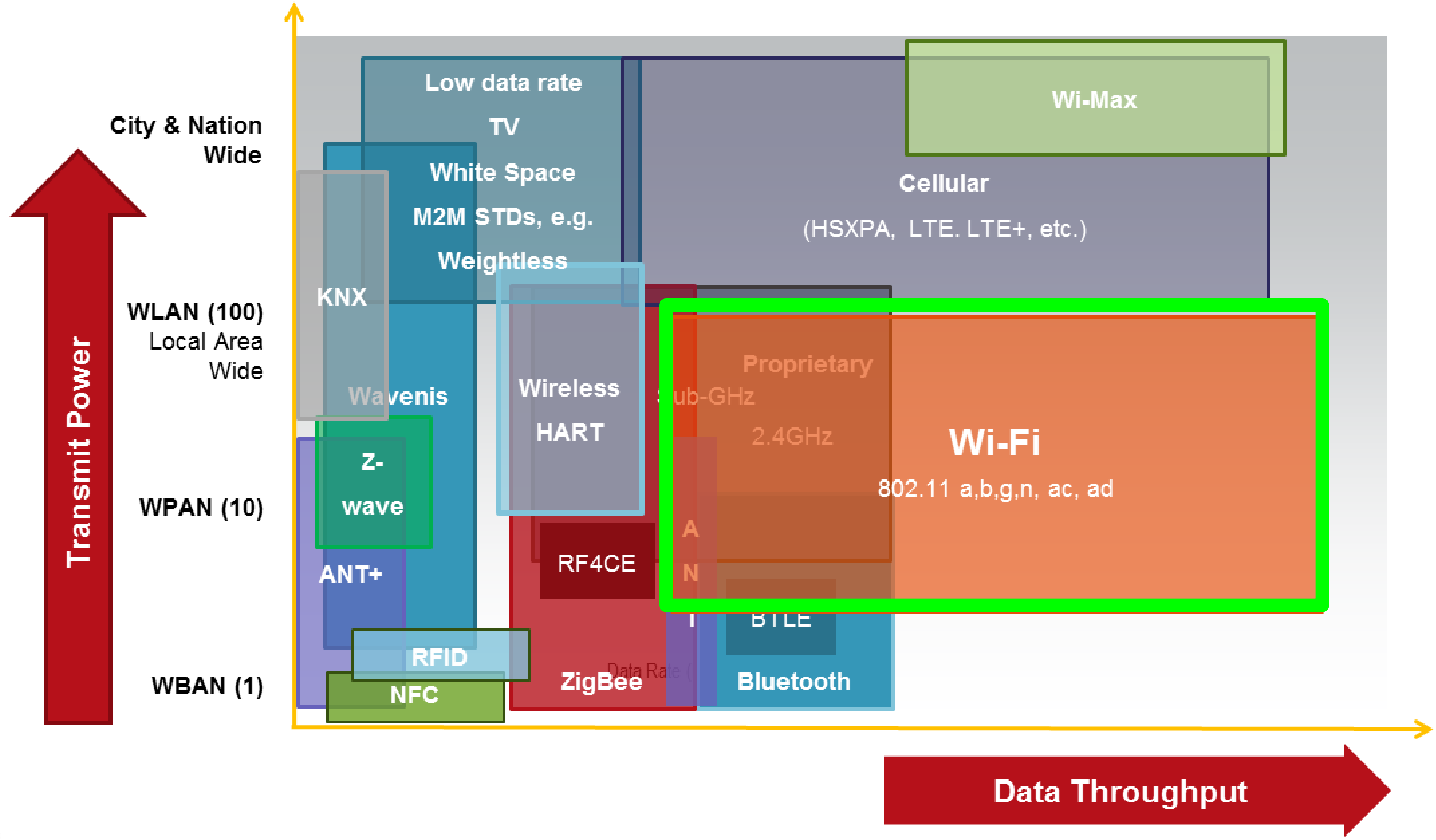
Overview Of Popular Wireless Standards

Wireless Technology	Version	Frequencies	Max Data Rate	Range	Network Application	Max Power Permitted	Focus	Typical Application
WiFi	802.11a	5.0 GHz	54 Mbps	30m	WLAN	-	Data Rates	Home Networking
	802.11b	2.4 GHz	11 Mbps	30m				
	802.11g	2.4 GHz	54 Mbps	30m				
	802.11n	2.4/5.0 GHz	600 Mbps	50m				
	802.11ac	5.0 GHz	1.7 Gbps*	50m				
	Wi-Fi Direct	2.4/5.0 GHz	250 Mbps	-	WPAN	-	Peer-to-Peer / wire replacement	Consumer electronics (peer-to-peer)
ZigBee	802.15.4	888 MHz 915 MHz 2.4 GHz	20 Kbps 40Kbps 250 Kbps	30m	WPAN	1W	Low Cost Low Power Low Latency	Energy Management Industrial Control Consumer electronics
Bluetooth	v1.x	2.4 GHz	1 Mbps	Class 1: 100m	WPAN	Class 1: 100 mW	Peer-to-Peer / wire replacement	Handsets, PC Peripherals
	v2.x +EDR	2.4 GHz	3 Mbps	Class 2: 10m		Class 2: 2.5 mW		
	v3.x +HS	2.4 GHz	24 Mbps	Class 3: 1m		Class 3: 1 mW		
	v4.x (LE)	2.4 GHz	1 Mbps			0.01 - 0.5 mW	Low Power	Remote Sensors



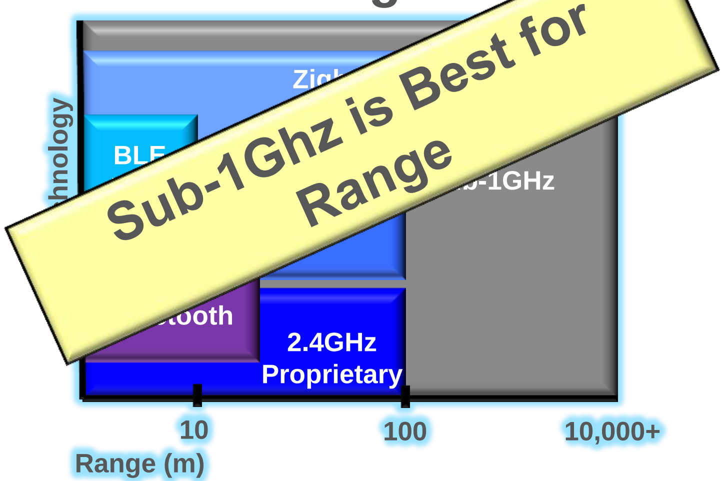
Overview Of Popular Wireless Standards

- Wi-Fi is popular for WLAN and WPAN applications
- Wi-Fi spans a wide-range of data rates

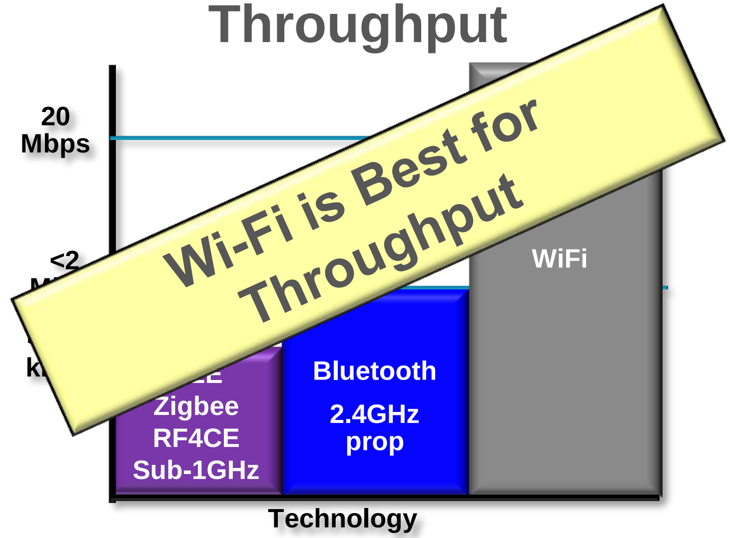


Choosing The Right Technology!

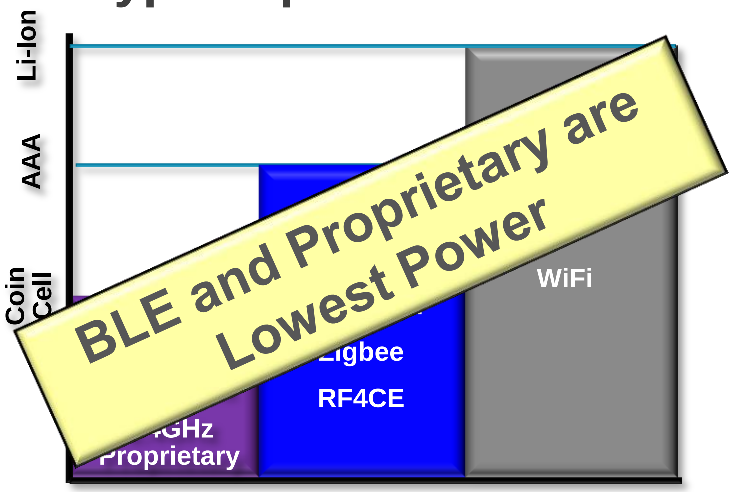
Range



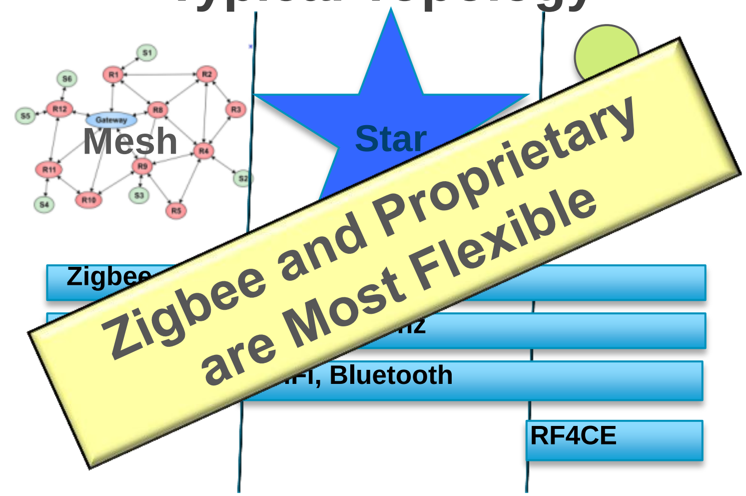
Throughput



Typical power source



Typical Topology



Avnet For Wireless Solutions!

- The focus of this training is **Wi-Fi** connectivity, using wireless modules with **Zynq** Linux-based designs.
- Avnet has a strong wireless portfolio and FAEs are available to assist with researching **all** wireless solutions (devices, modules, reference designs…)

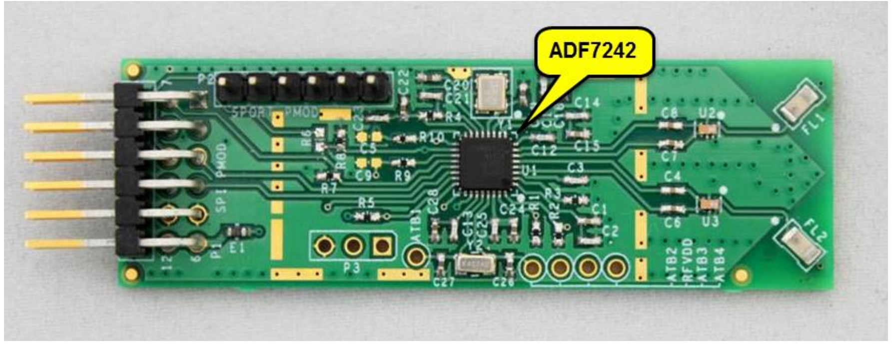
- Sub 1GHz
- ANT
- 6LowPAN
- Zigbee
- BT/BLE
- NFC
- 3G/4G Cellular
- and others…

- IR temperature
- Humidity
- Magnetometer
- Gyroscope
- Pressure/Altimeter
- Accelerometer
- Ambient Light

IEEE 802.15.4 (6LoWPAN, Zigbee, and others)

- 802.15.4 permits various LR-WPAN (low-rate, low-power) wireless protocols, ideal for Wireless Sensor Networks, eg.
  - **6LowPAN** (IPv6 Internet Protocol over 802.15.4)
  - **Zigbee** (Mesh-networking)
- New Analog Devices 802.15.4 transceiver board available
  - Pmod-compatible, SPI interface board (p/n: **EVAL-ADF7242-PMDZ**)
  - 6LoWPAN based Reference Design for Zedboard
- MAC802154 Linux driver natively supports IPv6 / 6LoWPAN
  - Other 802.15.4 wireless protocol stacks can be added…
- CoAP (Constrained Application Protocol)
  - Facilitates rapid implementation of IPv6 based applications

Available Oct’2014



IEEE 802.11 (Wi-Fi)

- Family of specs from IEEE for WLAN technology:
  - covers wireless MAC and PHY for 2.4 GHz and 5 GHz ISM bands
- Specifies the over-the-air interface:
  - between a wireless client and a base station
  - between two wireless clients
- In network stack, appears to Logical Link Control layer as:
  - IEEE802 wired LAN
- 802.11b/g adequate for medium-traffic applications
  802.11n/ac recommended for higher data throughput

	802.11a	802.11b	802.11g	802.11n	802.11ac
RF Band	5 GHz	2.4 GHz	2.4 GHz	2.4 GHz or 5 GHz	5 GHz
Data Rate (max)	54 Mbps	11 Mbps	54 Mbps	600 Mbps	1.7 Gbps
Modulation	OFDM	DSSS or CCK	DSSS or CCK or OFDM	DSSS or CCK or OFDM	OFDM
Channel Width	20 MHz	20 MHz	20 MHz	20/40 MHz	20/40/80/160 MHz
Spatial Streams	1	1	1	up to 4	up to 8

Wi-Fi: IEEE 802.11 Overview

- Over 2.5 Billion Wi-Fi units deployed,
  - 1 Billion+ / year being added!
- Wi-Fi Alliance trademark certifies interoperability
- Easiest connection to the Internet
  - Native to IP and TCP
  - Smartphone and Tablet support
  - Global use of 2.4 GHz and 5 GHz unlicensed ISM bands
- *Noteworthy Trends…*
  - Wi-Fi Direct / Wi-Fi P2P / ad hoc (Peer-to-peer connections)
  - Wi-Fi Display (Peer-to-peer media streaming to HDTV)
  - Wi-Fi network co-processors (for embedded M2M)
    - use of an Embedded network stack for simpler connectivity
  - Super Wi-Fi and the use of 50-700MHz TV-band white space

Wi-Fi: 802.11 Security

- Two aspects of security are addressed in 802.11:
  - **Authentication** (Secure Network Access Control)
  - **Link Encryption** (data is encoded, a secret key required to decode)
- Shared key **authentication** schemes include:
  - WEP, WPA, WPA2

- Data path, **link encryption** methods:
  - WEP, TKIP, AES
- WPA2, AES capable modules should be used!
  - WPA2-PSK: Distributes pre-shared keys from A/P to wireless clients
  - WPA2-802.1X / EAP: (Good for enterprise) Combines A/P authentication with server authentication of user credentials
  - WPA2 includes 128-bit AES encryption (never been ‘cracked’)
- Secure configuration of Network Settings
  - WPS2 and SmartConfig are popular secure provisioning methods

Design Considerations When Adding Wireless To Zynq

Wireless Design Considerations

Multiple aspects to consider when adding wireless: eg.

- **Standard** (interoperable) or **proprietary** solution?
- **Frequency** vs **Range** and **market needs**?
- **Range** vs **Power** consumption and **Data Rate**?
- **Regulatory** requirements?
  - Narrowband duty cycle limits
  - International variation of standards
- **Discrete** (Radio + MCU), **SoC,** or **Module** solution?
- **Interface** options?
- Availability of **protocol stacks** and **drivers** for my OS ?

Design Checklist Priorities

1. Wireless Performance Requirements ✓
2. Host Processor considerations ✓
3. Host interface bus types and software drivers ✓
4. PCB design, antenna and certification aspects ✓
5. Strategies to minimize power consumption ✓

The following slides elaborate briefly on a subset of key questions and tradeoffs in each of these areas…

LS Research is a good place to go for additional reading:
www.lsr.com/white-papers

Wireless Performance Requirements (1 of 2)

- **Max vs Actual Throughput Requirements?**
  - Type of host interface will limit the data throughput rate eg. UART: 2 Mbps, SPI: 8 Mbps, SDIO: 80 Mbps

- **Wi-Fi Protocols, Frequency Bands, Channel Width, SISO/MIMO, Number of Spatial Streams…?**
  - IEEE802.11 b/g/n/ac, Dual band (2.4GHz and 5GHz), 20MHz/40MHz channel width, SISO/MIMO

- **TX Power, RF Transmitter Power And Range?**
  - Active power consumption (in mA) an indication of efficiency
  - RF Tx Power (in dBm) is a key factor in determining usable range

Wireless Performance Requirements (2 of 2)

- **RX Power, RF Receiver Sensitivity And Link Budget?**
  - *RF Sensitivity*: lowest power level (received signal strength) at which receiver can detect RF signal and demodulate data.
  - *Link Budget*: accounts for all gains & losses from Tx to Rx
  - *Rx Power* : is a function of Tx power, Tx and Rx Gain, Range and Wavelength (as summarized by the "*Friis transmission equation*")

$$\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi R} \right)^2$$

  - 2x Range improvement can be achieved by:
    4x the Tx Power ***OR*** -6dB of Rx Sensitivity!
  - 2.4 GHz has better range but more interference than 5 GHz
  - Tx and Rx Gain can be increased by using an external antenna (a later slide details external antennas from *TE connectivity*)

Host Processor Considerations

- **Host Processor Requirements**
  For Zynq: TCP-IP network stack and Wi-Fi supplicant on the host

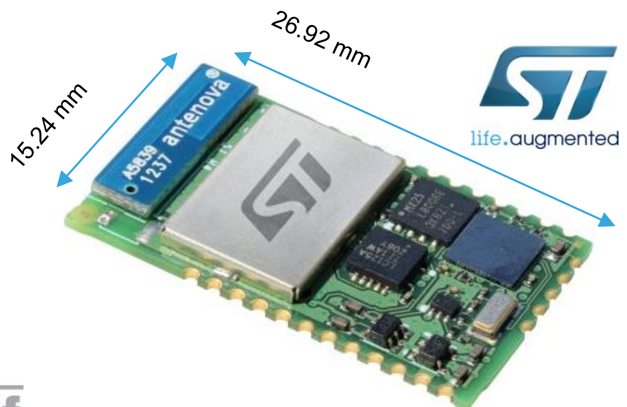
- **Security And Modes Supported**
  eg. WEP, WPA-Enterprise, WPA2 (- see Security slide)

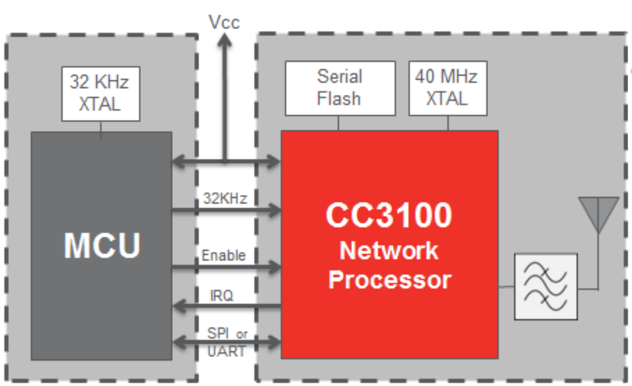
- **OS Integration With Zynq?**
  How much effort required to integrate-, or port this to Zynq?

- **Host Interfaces And Availability Of Software Drivers?**
  Features and limitations of the different host interface types:
  UART, SPI, SDIO, USB, PCIe
  (covered in the next 3 slides…)

Host Interface Bus Types And Software Drivers

- **UART** and **SPI**
  - Relatively slow, UART relies on “AT”-type interface
  - No integration with Linux Networking functions!
  - Both interface types popular for Network Coprocessor use (ie. wireless module together with a companion MCU)
  - Popular 802.11bgn Wi-Fi examples:
    - Serial to Wi-Fi module : **STMicro SPWF01**
    - SPI/Serial Wi-Fi module: **TI SimpleLink CC31xx** (SPI: 20 MHz, UART: 3 Mbaud)





Host Interface Bus Types And Software Drivers

- **USB** and **PCI Express**
  - High throughput but availability and Linux driver support can be an issue
  - Both types vulnerable to rapidly changing consumer market. Longevity and availability not guaranteed!
  - An example detailing USB dongle approach is documented on www.zedboard.org
    - Discusses Ralink based USB dongle with Zedboard
    - Provides insights into Kernel config settings for this type of adaptor
  - A PCIe host interface adds cost and power-consumption
    - Requires a Zynq device with high-speed transceivers
    - Notable use case is for the demanding **802.11 AC host interface**

Host Interface Bus Types And Software Drivers

- **SDIO**
  - High data throughput using 4 lane SDIO
  - Linux drivers and Linux integration available
  - Good product longevity
  - Availability of Industrial grade devices
  - Best choice for embedded Zynq designs (SDIO interface implemented using MIO pins)
  - In-Band and OOB interrupt mechanisms (OOB hardware IRQ pin used for best results)

Pmod Pin#	Zynq Pin	WL8 Pinout	SN8K Pinout
1	MIO_13	SDIO_D1_WL	SDIO_D1
2	MIO_10	SDIO_D0_WL	SDIO_D0
3	MIO_11	SDIO_CMD_WL	SDIO_CMD
4	MIO_12	SDIO_CLK_WL	SDIO_CLK
7	MIO_0	WLAN_IRQ	OOB_IRQ
8	MIO_9	WL_EN_SOC	RST_N
9	MIO_14	SDIO_D2_WL	SDIO_D2
10	MIO_15	SDIO_D3_WL	SDIO_D3

PCB Design, Antenna And Certification Aspects

- **Module Package Type, Size and Temperature Range**
  eg. Surface Mount, 14x21x2.4mm, Industrial -40 to +85˚C

- **Type of Antenna**
  eg. Chip antenna or U.FL connector, Omni-directional or Directional, SISO or MIMO configuration, single or dual band

- **Certifications and Compliance**
  eg. FCC, IC, ETSI, etc certifications (detailed on later slides)

- **Availability of Development Kit for Prototyping**
  eg. WL1835MODCOM8B: WiLink-8 Module WiFi + Bluetooth Kit

Certifications & Compliance

- Two Types of FCC Testing:
  - **General Emissions** : all boards require this ($1K to $3K) (FCC Part 15**b** / IC, CE, Telec, etc)
  - **Intentional Radiation**: for boards with wireless ($25K+) (FCC Part 15**c**)

- FCC “Modular Grant” (Modular Approval)

  Certified reference designs provide a method to minimize FCC testing requirements (ie. Part 15c, Intentional Radiator section). It permits use of module supplier’s FCC ID on the end product, provided aspects like PCB layout of antenna circuit are matched to that of reference design.

- If external antenna is used with a module that has FCC certification based on a chip antenna, then a “Class-II Antenna Modification” filing is required.

Certifications & Compliance

	• Certified for United States • FCC test reports are recognized by other countries for filing!
Industry Canada	• Certified for Canada • Accepts FCC test reports for filing certifications
	• FCC/ETSI testing is recognized by 40+ countries for filing • CE Radio Approval

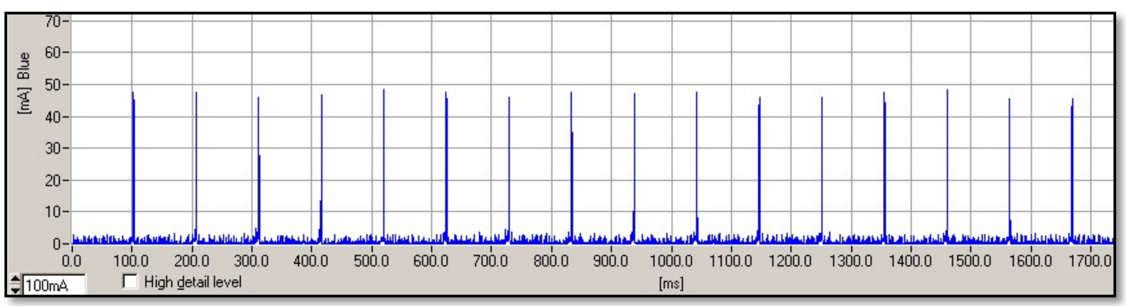
- FCC/ETSI test reports are accepted by other regions!
  - Can be used to file for certifications in 40+ *other* countries
  - Some in-country paperwork and fees may still be required
- Pre-certified modules
  - Reduces cost, risk and delays associated with adding wireless!

Interoperability Certifications

- When porting Linux wireless software stacks from other processors to Zynq, this aspect may require attention.
- If trademark Wi-Fi and Bluetooth logos are to be displayed on end product, interoperability certification is needed from:
  - **Wi-Fi Alliance** - WFA is a trade association who administer Wi-Fi interoperability and conformance certification
  - **Bluetooth SIG** - administer Bluetooth "Qualification Program" for interoperability and conformance certification
- For Wilink-8 :
  - Wi-Fi: pre-certification is possible if same Linux Kernel and configuration as AM335x is used (as in TI's Sitara Linux SDK)
  - Bluetooth: Wilink-8 BT Controller has been pre-certified by BT SIG (and Wilink-8's QDID may be used), but overall certification will depend on which Bluetooth stack is used

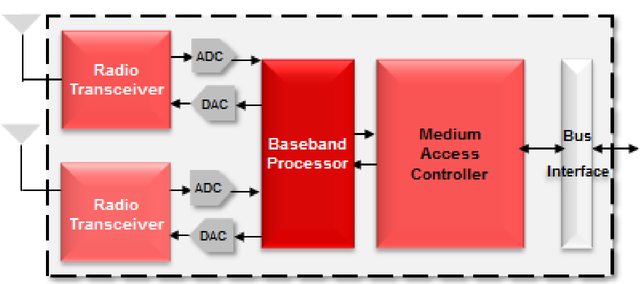
Strategies To Minimize Power Consumption

- Power efficiency and portable operation often a requirement in wireless-enabled products!
- PM frameworks in Linux kernel (eg. Suspend-to-RAM) facilitate Suspend/Resume control of the Zynq processor.
- An advanced topic but User Apps can be developed to implement this with:
  - Wake-on-WLAN when a specific packet detected by wireless module
  - Use of a low-power companion MCU (Freescale's X-Fest demo has an MCU controlling Zynq's power rails but the companion Zynq design may be adapted for Suspend/Resume schemes)



Strategies To Minimize Power Consumption

- Host control of Wireless Module's power is also possible
  - Wilink-8 allows independent control of WL_EN and BT_EN pins
- Avnet Wi-Fi Pmod adaptor solutions have 32kHz clocks to support low deep sleep modes
- Wireless Module considerations in context of power include:
  - Use of SISO or MIMO mode (MIMO2 typically ~50% more power)
  - Reducing Tx Power has big impact on range but is less of a factor in improving overall power efficiency
  - Higher modulation schemes = more efficient data transfer! (eg. 64 QAM in 802.11**n** vs 256 QAM in 802.11**ac**)
  - Frame Aggregation and Block ACKs (in 802.11n and ac) also bring significant improvements in efficiency



MIMO

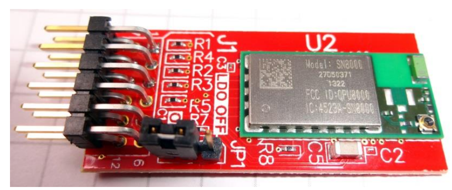
Adding Wi-Fi To Linux Based Zynq Designs

SDIO-based Wi-Fi For Zynq Linux Designs

Modules with SDIO interface to host processor are the ideal choice for embedded Linux applications.

Two **Avnet-designed** adaptors suitable for use with Linux-based designs on MicroZed and Zedboard are available:

- Murata SN8000 Pmod Wi-Fi Adaptor
  - Broadcom BCM43362 based Wi-Fi module
    - 802.11bgn Wi-Fi
    - SDIO host interface
    - Linux Drivers provided



- Wilink-8 COM to Dual Pmod Wi-Fi and BT Adaptor
  - TI WL1835MOD-based combo module
    - 802.11bgn Wi-Fi
    - Bluetooth 4.0 + BLE
    - Linux Drivers provided

Avnet WiLink-8 Pmod Adaptor

- COM8 to dual Pmod adaptor card
- Facilitates use of TI's WL1835MODCOM8B module with Avnet's MicroZed and Zedboard Xilinx boards
- Wilink-8 combo device supports Wi-Fi and BT/BLE
- Linux drivers provided for Wi-Fi and BT/BLE stacks on the Zynq host processor
- WL1835 COM8 module is FCC/ICC **certified**! Includes on-board MIMO 2x2 configuration chip antennas <u>and</u> U.FL connectors for optional external antennas
- Wi-Fi host interface : SDIO (4bit, high speed)
  BT/BLE host interface: UART

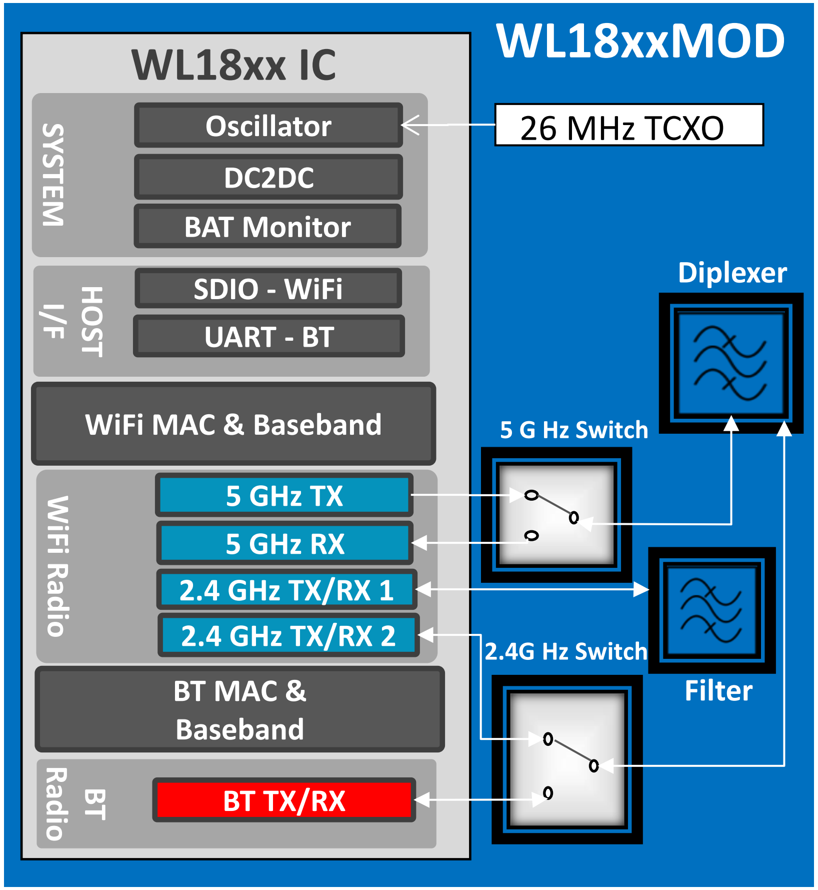
WiLink-8 Module Series

- 2.4GHz wireless modules with 2x2 MIMO capability
- 5GHz operation now added with dual band versions, qualified to Industrial temperature range

Product Name	WiFi .11bgn	WiFi .11abgn	WiFi MIMO	WiFi MRC	BT4.0
WL1801MOD	•				
WL1805MOD	•		•	•	
WL1831MOD	•				•
WL1835MOD	•		•	•	•

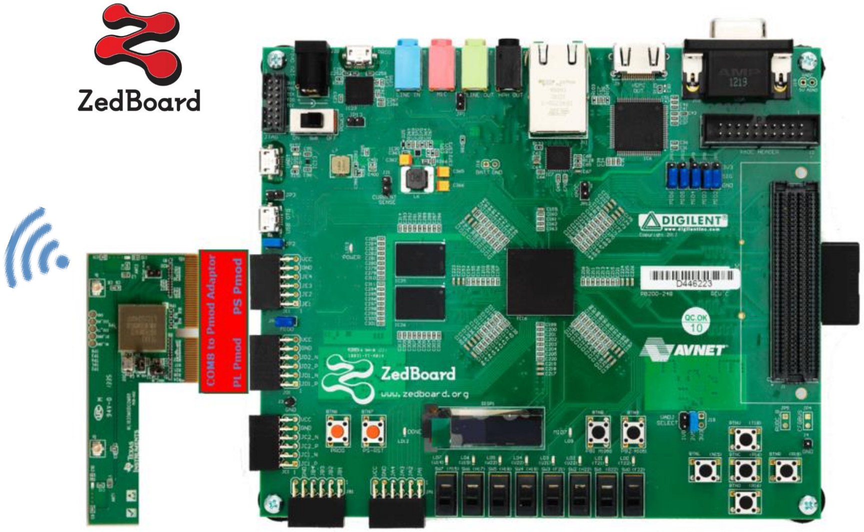
Product Name	WiFi .11bgn	WiFi .11abgn	WiFi MIMO	WiFi MRC	BT4.0	Industrial Temp. Range
WL1833MOD	•	•			•	•
WL1836MOD	•	•		•	•	•
WL1837MOD	•	•	•	•	•	

5GHz production parts available Dec'2014

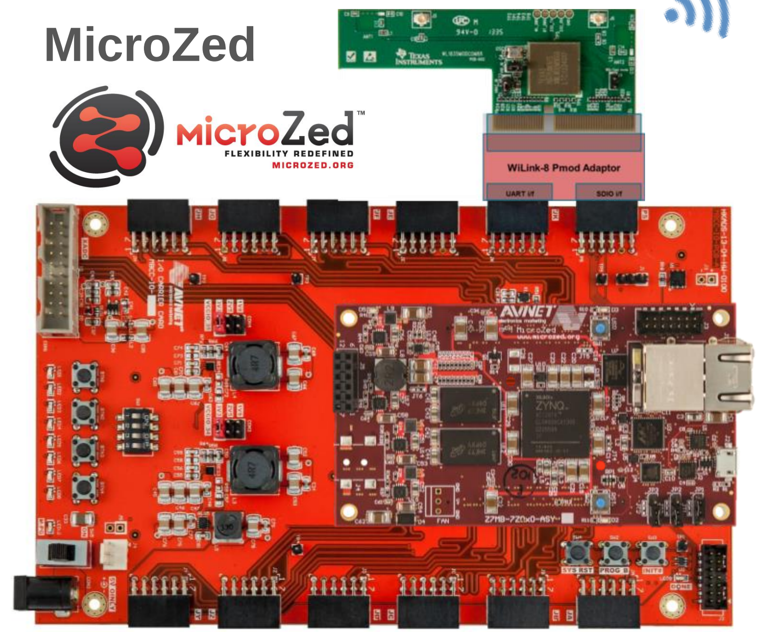


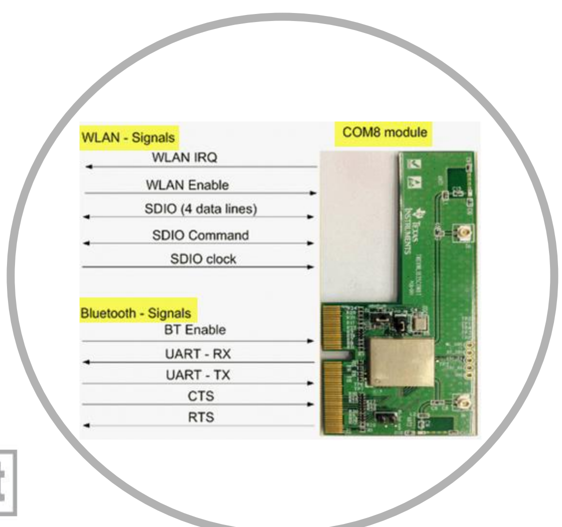
Wilink-8 Adapter With Zedboard And MicroZed

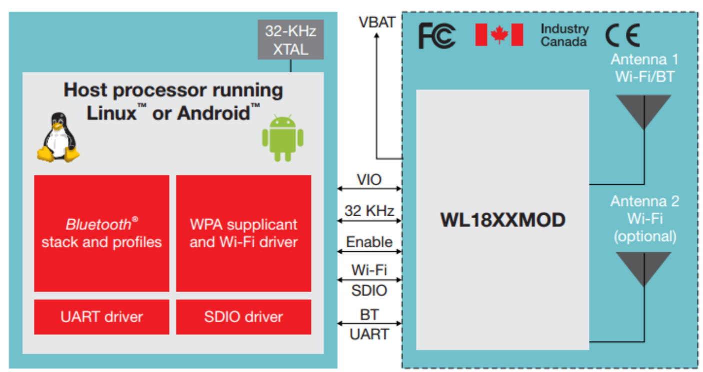
ZedBoard



MicroZed

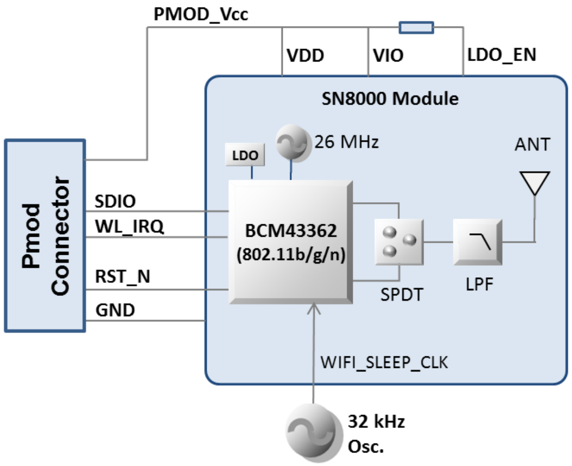


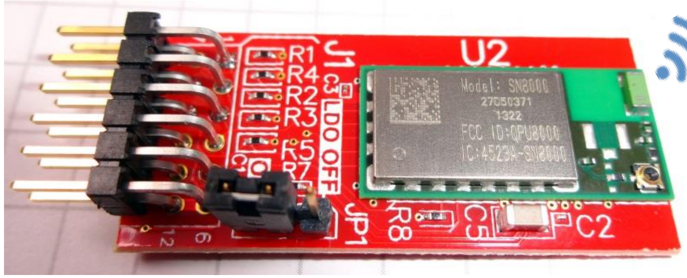




Avnet Murata SN8000 Wi-Fi Pmod

- Avnet designed Murata SN8000 based 802.11bgn Wi-Fi module (uses Broadcom BCM43362 device)
- Pre-certified module with onboard chip antenna
- Linux drivers provided, Network Stack is run on the Zynq host processor, Security Supplicant is on the BCM43362
- Small form-factor board, 4bit SDIO host interface clocked at up to 50 MHz over a single 2x6 Pmod connector
- Good feature set (eg. supports advanced security types, concurrent STA, soft AP, WiFi Direct, etc…)





Use Of External Antennas (optional)

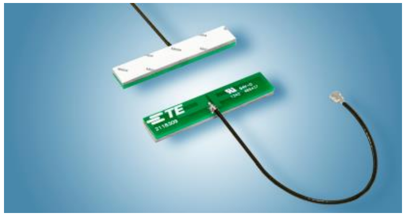
- Modules typically are also available with U.FL connector for the attachment of external antenna.
- Use of high Gain external antenna ensures maximum range and data throughput.
- Suitable *"Standard Cabled Antennas"* from *TE Connectivity* are shown tabled below:

Part Number	Frequency Range (MHz)	Standard	Peak Gain (dB)	VSWR
1513381-1	3100 – 6000	UWB	+4	<3.0:1
1513472-5	2400 – 2485.5, 5150 – 5875	BT, Wi-FI, ZigBee	+3	<3.0:1
2118059-1	2300 – 3800	BT, Wi-FI, ZigBee	+4	<3.0:1
2118060-1	2300 – 3800, 5150 – 5875	BT, Wi-FI, ZigBee	+2	<3.0:1
2118326-1	4900 – 5875	Wi-Fi	+2.4	<2.5:1
2118309-1	2400 – 2483.5, 4900 – 5875	BT, Wi-FI, ZigBee	+3.7	<2.0:1

1513381-1, 1513472-5

2118059-1, 2118060-1

2118326-1



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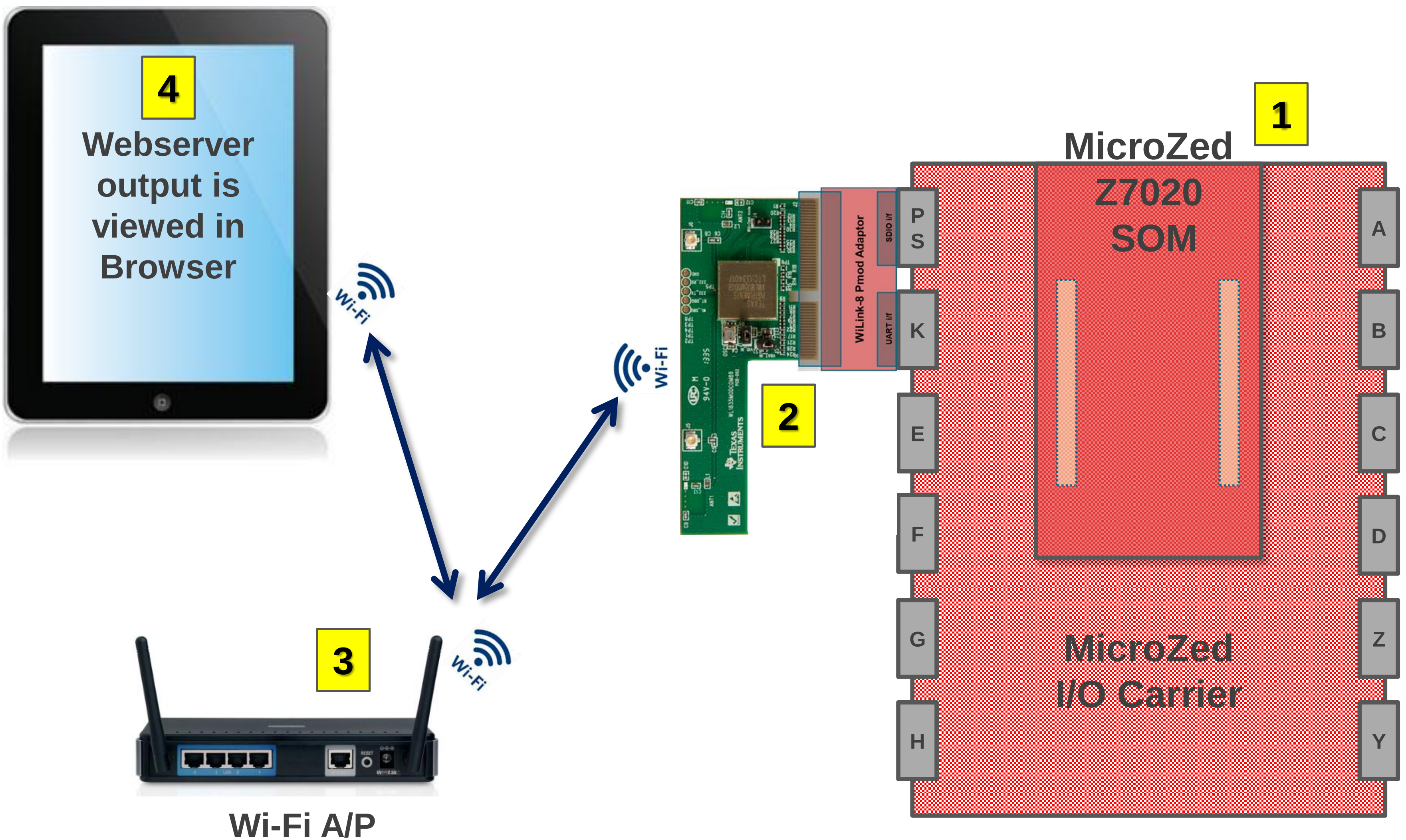
Example: Adding A Wi-Fi Module To MicroZed

Proof of Concept

Wilink-8: Wi-Fi Reference Design System Setup



Wilink-8: Key Steps For Adding Wi-Fi

1. Configure and Build the Hardware Platform
2. Generate Updated Zynq Boot Image
3. Configure and Build the Device Tree
4. Configure and Build the Linux Kernel and Drivers
5. Configure Wi-Fi Network Connection and Test

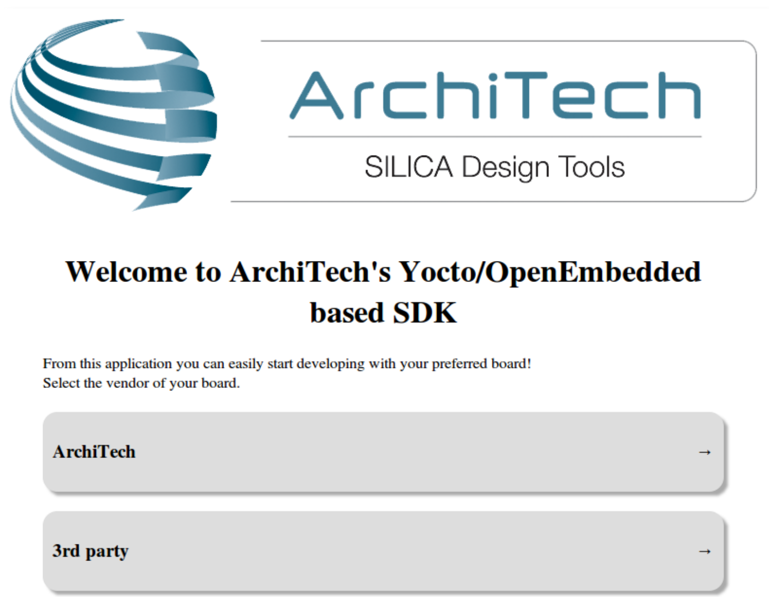
Wilink-8: Procedure Notes…

These slides describe a subset of key steps in the hardware definition and build of Linux image for Wilink-8 based Wi-Fi on a MicroZed reference design.

- Xilinx Toolchain = Vivado 2014.2 toolchain
- Target OS = linux-xlnx (xlnx_3.14 checkout tag)
- TI Linux driver version tag = ol_r8.a9.14
- Linux build is automated with scripts that target ArchiTech's Yocto Zed SDK (v1.1.0)
- "Proof of Concept" design files and documentation detailing all steps will be made available for download

Scripted build (ArchiTech Yocto SDK)

- At this time a scripted build is available for use with Yocto ZED SDK v1.1.0 from ArchiTech (Silica)
- Target is MicroZed (with or without IO Carrier Card) but has also been tested with ZedBoard
- Scripting for other build methods and target boards is also planned...

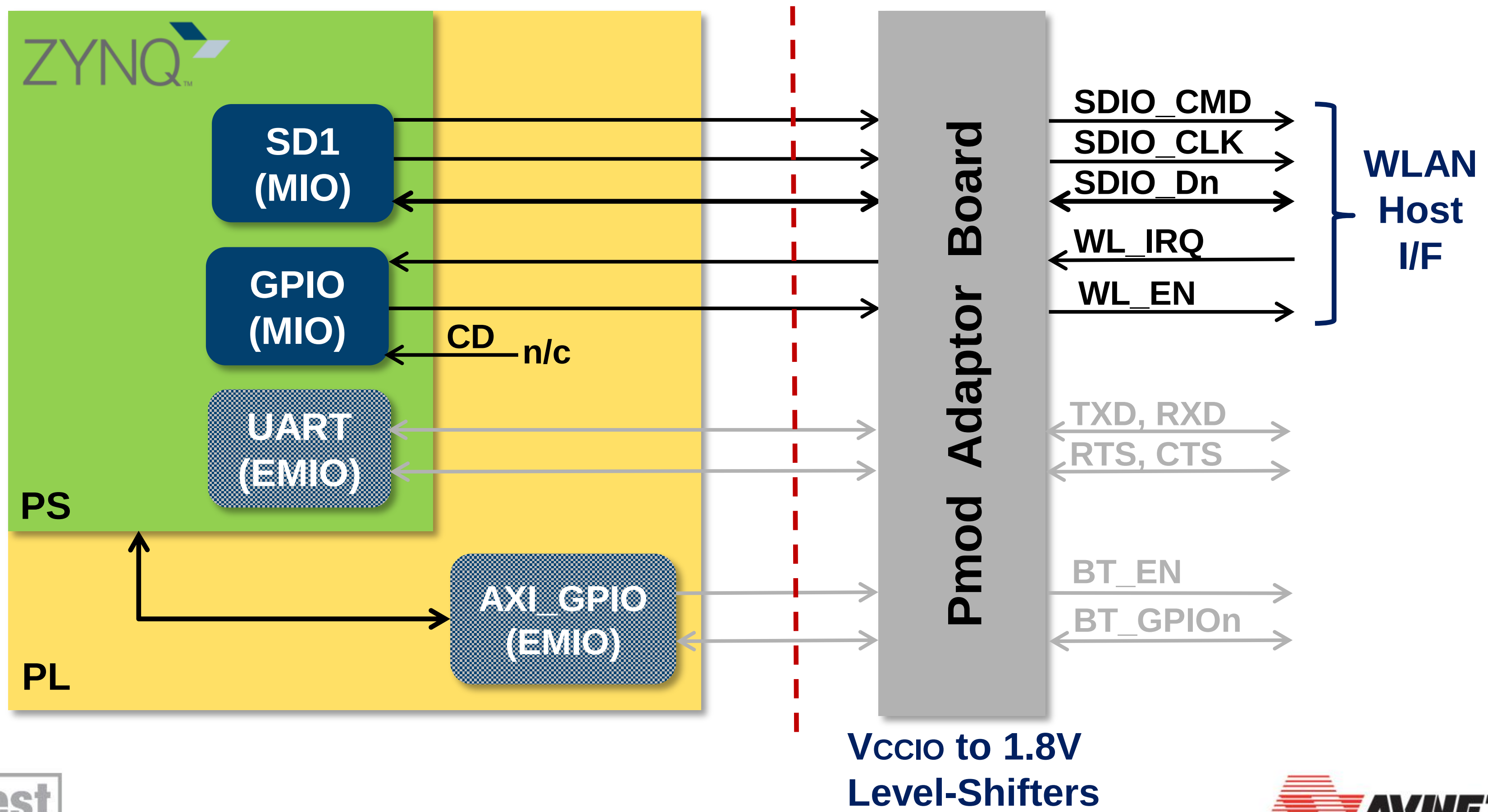


uz_wl8_TI_software_package.sh
uz_wl8_file_system.sh
uz_wl8_boot_loader.sh
uz_wl8_kernel.sh
uz_wl8_SDcard.sh

Step1: Configure + Build H/W Platform

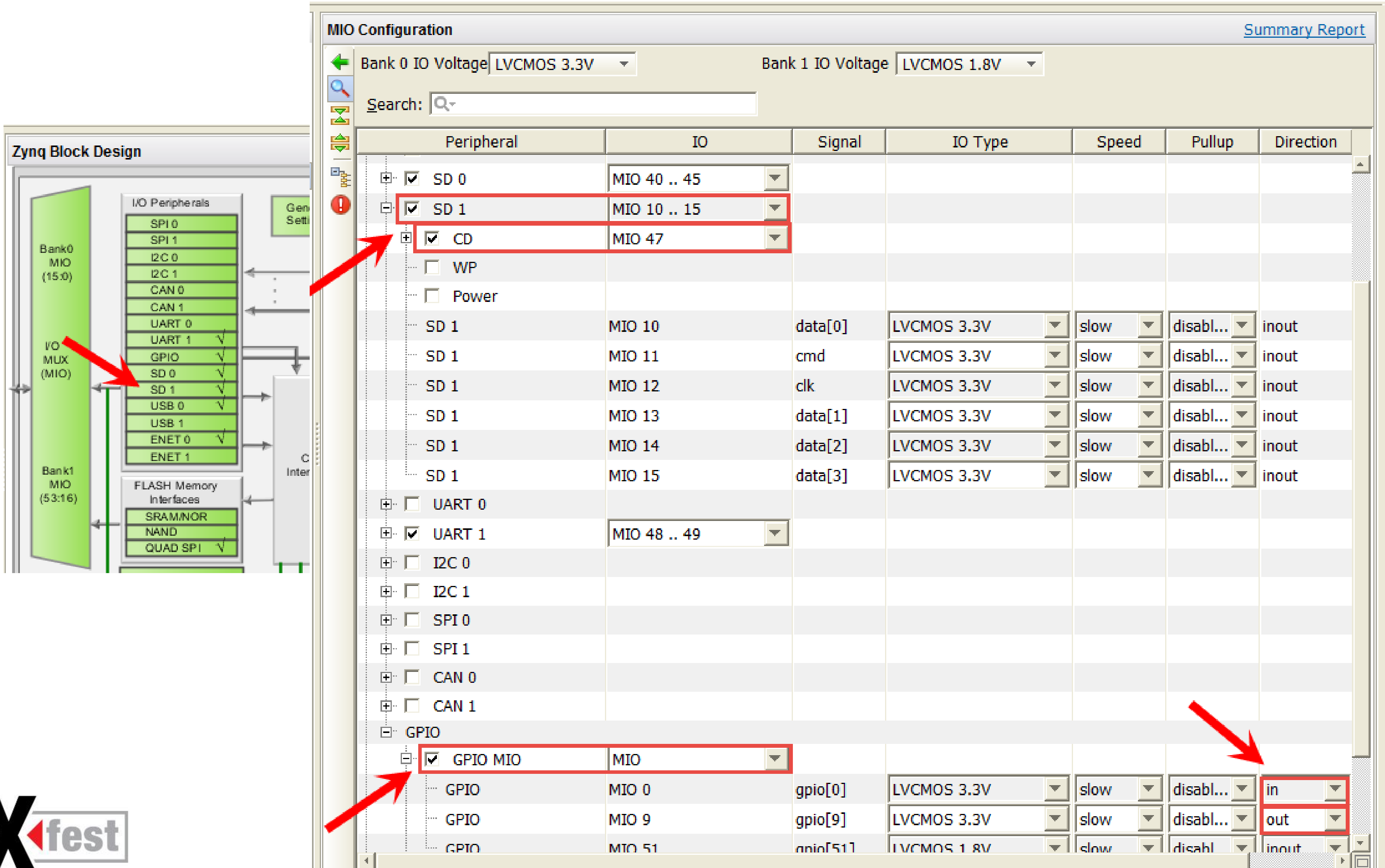
Add WLAN host interface to the Zynq H/W platform definition

- SD1 (4bit SDIO) and two GPIOs (WL_EN, WL_IRQ)
- All are on MIO to the PS Pmod connector



Step1: Add WLAN Host Interface

- Use IP Integrator to add SD1, WL_EN and WL_IRQ…

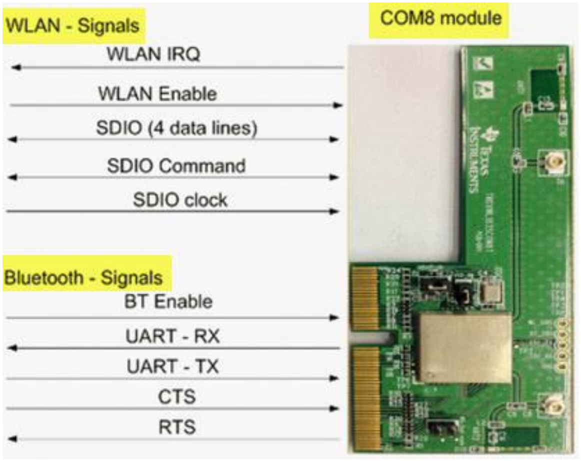


Step1: Add WLAN Host Interface

- Because WLAN interface uses only PS MIO pins:
  - no pinout constraints need to be added to .xdc file !
  - no interrupt from PL needs to be configured in GIC!
- (If the BT interface is added, PL EMIO pins are used)
- Run Implementation and Generate Bitstream
- Export Hardware Design to SDK

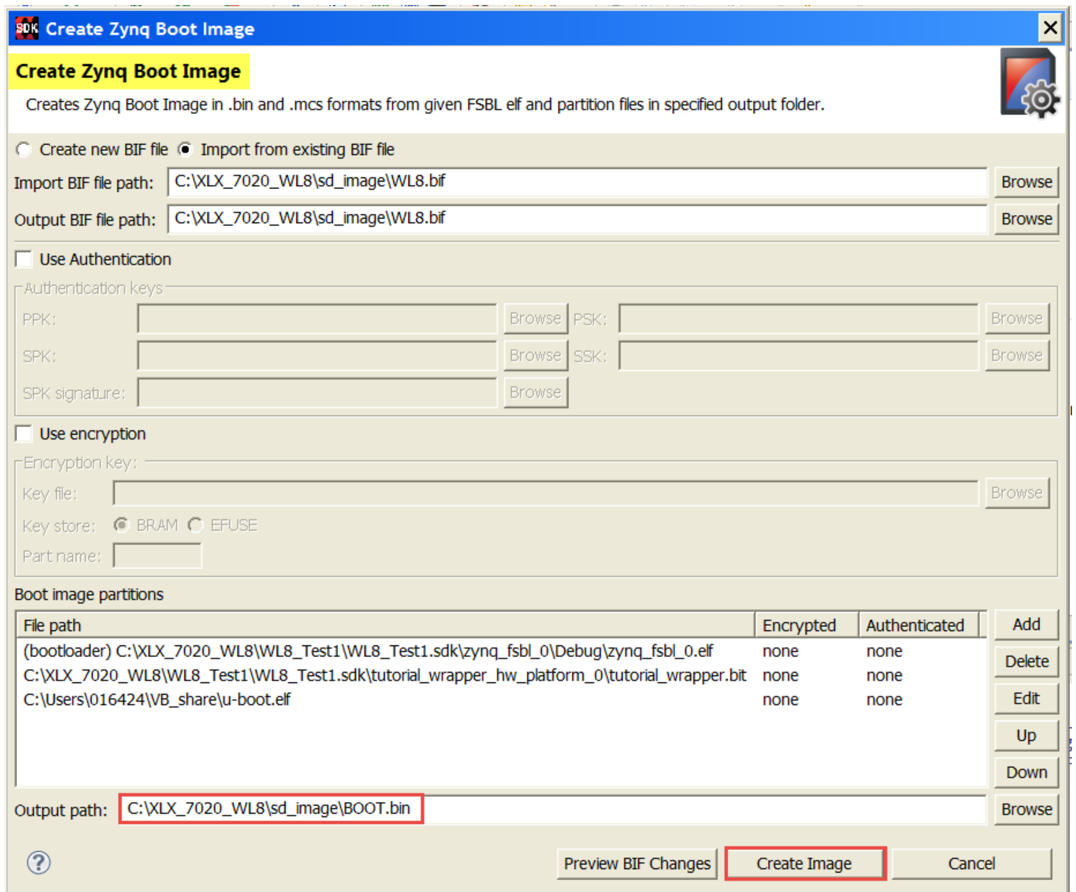
PS Pmod Connector (WLAN)

Pmod Pin#	PS MIO Pin	Signal Name	Pmod Pin#	PS MIO Pin	Signal Name
1	MIO 13	SDIO_D1	7	MIO 0	WL_EN_SOC
2	MIO 10	SDIO_D0	8	MIO 9	WLAN_IRQ
3	MIO 11	SDIO_CMD	9	MIO 14	SDIO_D2
4	MIO 12	SDIO_CLK	10	MIO 15	SDIO_D3
5		GND	11		GND
6		VCC	12		VCC



Step2: Generate Updated Zynq Boot Image

- Because the **bitstream** has changed, new files need to be generated in **SDK**
- Zynq Boot Image file (boot.bin) _must_ be re-generated
  - Use SDK **Create Zynq Boot Image** tool to create this file



zynq_fsbl_0.elf
\+ bitstream.bit
\+ u-boot.elf
= **BOOT.bin**

Step3: Configure + Build The Device Tree

- Using the provided device tree file as reference, add driver bindings into the .dts file for target board
- Edits need to be made in 3 sections of the .dts file:

Section/label	Driver binding definitions for:
wlcore	WL_IRQ Interrupt and clock config.
wlan_en_reg	WL_EN GPIO control of WLAN power
ps7-sdio@e0101000	SD1 interface

- Build the updated Device Tree binary (.dtb file)
- The referenced “wlcore” driver files are located in the root file system at: **/drivers/net/wireless/ti/wlcore/**

Step3: Configure + Build The Device Tree

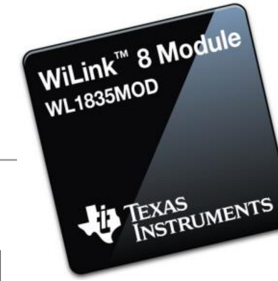
```
wlcore {
        compatible = "wlcore";
        interrupt-parent = <&ps7_scugic_0>;
        gpio = <0>;
        platform-quirks = <1>; /* use edge irqs for suspend/resume */
        board-ref-clock = <4>; /* if a 12xx card is there, configure the clock to WL12XX_REFCLOCK_38_XTAL */
};

wlan_en_reg: fixedregulator@1 {
        compatible = "regulator-fixed";
        regulator-name = "wlan-en-regulator";
        regulator-min-microvolt = <3300000>; /* Actually 1.8V, but this keeps the driver happy */
        regulator-max-microvolt = <3300000>;
        gpio = <&ps7_gpio_0 9 0x4>;          /* WLAN_EN GPIO for PS-Pmod MIO9: Bank0, pin9 */
        startup-delay-us = <70000>;          /* WLAN card specific delay */
        enable-active-high;
};

ps7_sd_1: ps7-sdio@e0101000 {
        clock-frequency = <0x2faf080>;       /* 50 MHz */
        clock-names = "clk_xin", "clk_ahb";
        clocks = <&clkc 22>, <&clkc 33>;
        compatible = "arasan,sdhci-8.9a";
        interrupt-parent = <&ps7_scugic_0>;
        interrupts = <0 47 4>;
        reg = <0xe0101000 0x1000>;
        xlnx,has-cd = <0x0>;                 /* Card Detect not used */
        xlnx,has-power = <0x0>;
        xlnx,has-wp = <0x0>;
        vmmc-supply = <&wlan_en_reg>;
        cap-power-off-card;
};
```

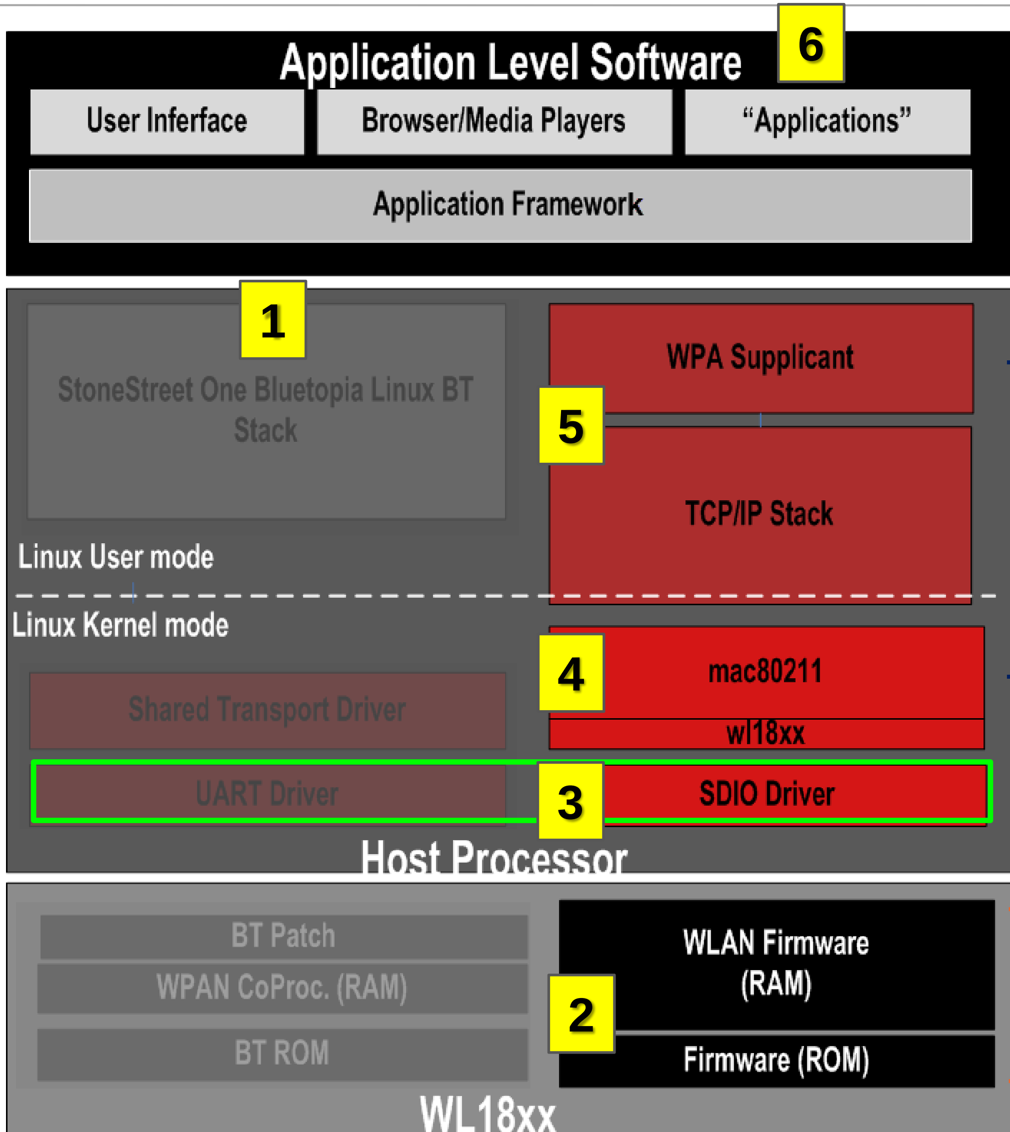
Step4: Configure + Build The Linux Kernel

- Configure and rebuild the Kernel with Wilink-8 WLAN support using the provided .sh script file (uz_wl8_kernel.sh) and Kernel **.config** file (zynq_wilink8.config)
- The key Kernel configuration changes are shown below…

```
-> Networking support                                      (CONFIG_NET [=y])
 -> Wireless                                               (CONFIG_WIRELESS [=y])
  -> cfg80211 - wireless configuration API                 (CONFIG_CFG80211 [=y])
  -> Generic IEEE 802.11 Networking Stack (mac80211)       (CONFIG_MAC80211 [=y])
-> Device Drivers
 -> Generic Driver Options
  -> Userspace firmware loading support                    (CONFIG_FW_LOADER [=y])
   -> Include in-kernel firmware blobs in kernel binary    (CONFIG_FIRMWARE_IN_KERNEL [=n])
 -> Network device support                                 (CONFIG_NETDEVICES [=y])
  -> Wireless LAN                                          (CONFIG_WLAN [=y])
   -> TI Wireless LAN support                              (CONFIG_WL_TI [=y])
    -> TI wl18xx support                                   (CONFIG_WL18XX [=y])
    -> TI wlcore support                                   (CONFIG_WLCORE [=y])
     -> TI wlcore SDIO support                             (CONFIG_WLCORE_SDIO [=y])
```

Wilink-8: Linux Wireless Stack Overview





Key to colors:

- 3rd Party/Customer Software
- Connectivity Host Software Components
- TI Device Software Components

Core Wi-Fi connectivity components are re-used without change:
- Linux Kernel 3.2.0
- WPA Supplicant v2.0
- mac80211 Driver (Source)
- WL18xx Firmware (Binary)

Connectivity Driver components in Kernel that may be changed:
- WLAN Host Interface (SDIO, WLAN_EN, WLAN_IRQ)
- BT Host Interface (UART)

WL18xx MAC + PHY functions

Wilink-8: Notes on Linux Wireless Stacks

Wi-Fi

- TI's WLAN Wilink-8 driver is included in Xilinx's open source **linux-xlnx** kernel
- Wilink-8 drivers in v3.14 linux-xlnx are not the latest!
- Drivers from TI Sitara Linux have been modified and replace the Wilink-8 driver code in linux-xlnx kernel
- (Will be submitted to Xilinx for inclusion in later releases of linux-xlnx)

Bluetooth/BLE

- BT stack options are:
  - StoneStreet One (fee based port to Zynq)
  - BlueZ (open source)

Step5: Verify Wi-Fi Driver and Functionality

- With updated uSD card inserted, reboot the board
- At Zynq's command-line prompt, use the following commands for a simple test of Wi-Fi connectivity

```
ifconfig wlan0 up
```

- PHY and firmware version will be reported, eg.

```
wlcore: PHY firmware version: Rev 8.2.0.0.212
wlcore: MAC firmware booted  (Rev 8.9.0.0.17)
```

- Scan for SSIDs of Wireless Access Points:

```
iw wlan0 scan | grep SSID
```

A response similar to the following will be seen…

```
SSID: HiltonHotSpot
SSID: ConferenceRoom1
```

Step5: Connect to A/P and Test

- Use the following commands to:
  - connect to a specific Access Point
  - verify this connection
  - request an IP address (assigned by DHCP server)

```
iw dev wlan0 connect X-Fest2014_IoT
iw dev wlan0 link
udhcpc -i wlan0
```

```
Lease of 192.168.1.101 obtained
```

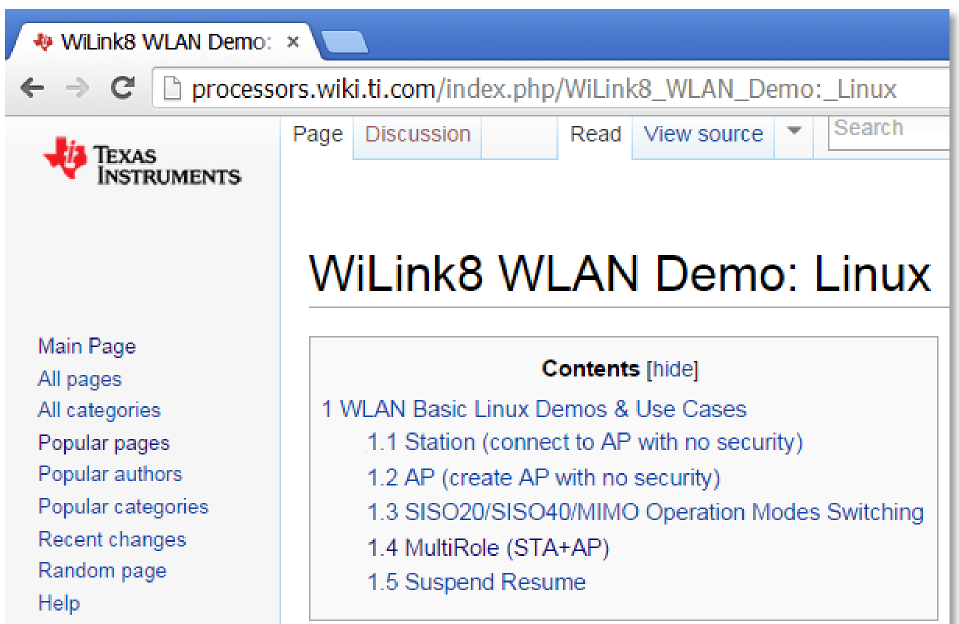
- Ping the reported IP address and check for response

```
ping 192.168.1.101
```

```
64 bytes from 192.168.1.101: seq=3 ttl=64 time=0.248 ms
```

Step5: Running the Webserver

- Once response from target board is verified, cut'n paste this IP address to the address bar of your browser (on any Tablet, Smartphone or Laptop connected to same Wireless A/P) in order to view the Webserver output
- More Linux-based tests are described at… http://processors.wiki.ti.com/index.php/WiLink8_WLAN_Demo:_Linux



Step5: Notes on Testing

Wireless Device Configuration Tools

The following tool package must be added to the host installation to facilitate testing (pre-installed in the scripted build from Avnet)

- **iw**
  - nl80211 based wireless device config utility (used in place of **iwconfig**)

Other Linux Wireless Tools may alternatively be used, eg.

- **iwconfig**
  - Wireless Tools (WT) package, facilitates access to the Wireless Extension (WE) generic API in the Linux kernel
    - Cross-compile and copy it to root filesystem (/usr/sbin)

Wi-Fi Demos

Wi-Fi Demos

- The Proof-of-Concept design will be available for download
- A pre-built image allows easy test/demo using MicroZed

ie.

1) Configure Network connections
2) Launch Webserver App on MicroZed from Zynq command prompt
3) Launch Browser on host laptop, tablet or smartphone (on same subnet)
4) Enter [ZYNQ_IP_ADDRESS] as webpage address
5) Observe and interact with webserver output

- X-Fest demos using Avnet Wi-Fi modules, include the following:
  - ***Industrial Intelligent Sensor System*** *(at Avnet table)*
  - ***Arduino Carrier Card Demo*** *(at Freescale table)*

Wireless Modules And Related Solutions Available From Avnet…

Avnet EMA – Wireless Module Linecard

	WLAN	BT/BLE	Combo	Sub-GHz	802.15.4	Cellular	GPS
Module Supplier	Texas Instruments Broadcom muRata Innovator in Electronics LS Research Wireless Product Development Inventek Systems Embedding Connectivity Everywhere Taiyo Yuden Panasonic ideas for life ST life.augmented Microchip bluegiga wi2wi TDK Digi	Texas Instruments Broadcom muRata Innovator in Electronics LS Research Wireless Product Development Inventek Systems Embedding Connectivity Everywhere Taiyo Yuden Panasonic ideas for life ST life.augmented Microchip bluegiga wi2wi Digi Anaren What'll we think of next? TDK	Texas Instruments Broadcom muRata Innovator in Electronics LS Research Wireless Product Development Inventek Systems Embedding Connectivity Everywhere Taiyo Yuden Panasonic ideas for life wi2wi Digi	LS Research Wireless Product Development muRata Innovator in Electronics Panasonic ideas for life ST life.augmented Microchip Anaren What'll we think of next?	LS Research Wireless Product Development muRata Innovator in Electronics Panasonic ideas for life Microchip Anaren What'll we think of next? MMB Networks	MultiTech Systems Quectel Wireless Module Expert	Texas Instruments Inventek Systems Embedding Connectivity Everywhere Taiyo Yuden wi2wi antenova m2m Quectel Wireless Module Expert

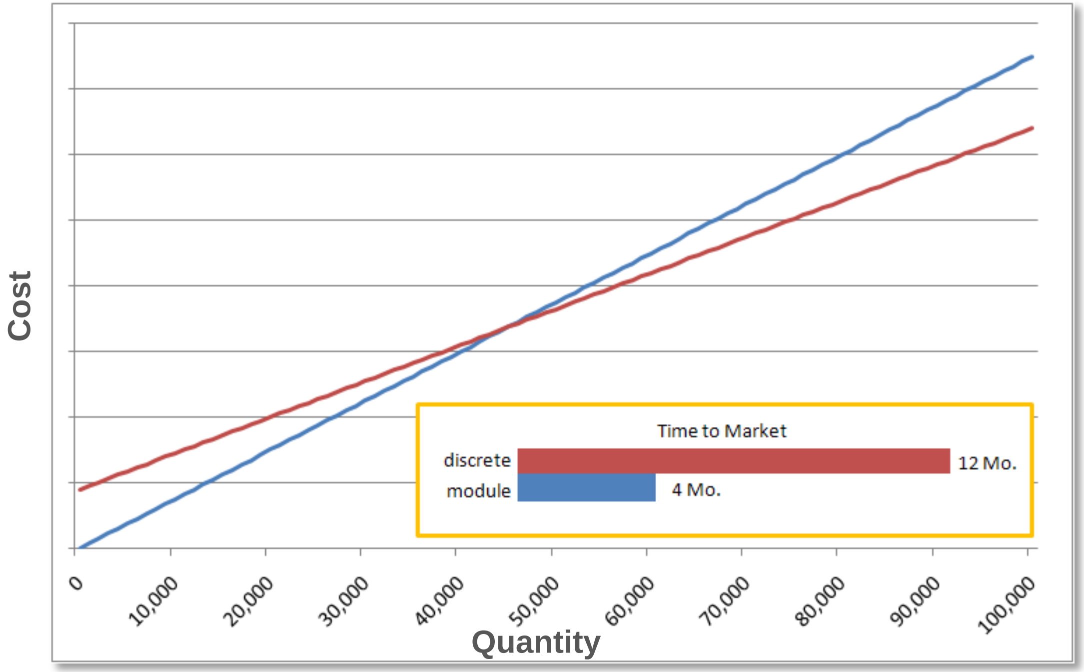
Xfest

AVNET

Wireless Modules: Make vs. Buy

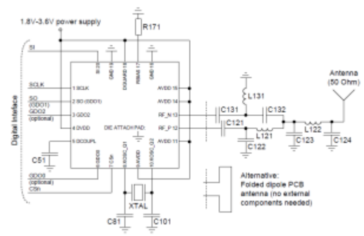
Make
- RF circuit design & layout
- Firmware
- Test & debug
  (time plus $$$ equipment!)
- *Re-spin?*
- Certification
- Multi-component BOM
- Fab & Test

Buy
- No design risk
- Pre-certified
- Assembled, tested, calibrated
- Smallest size
- One part number
- Shortest time-to-market

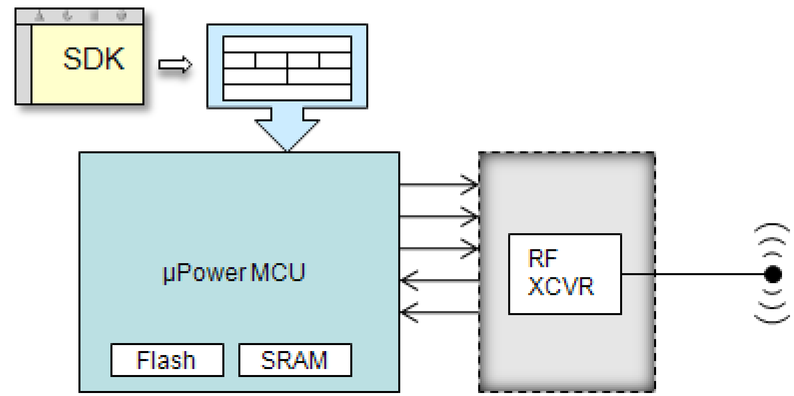


Design Strategies For Adding Wireless

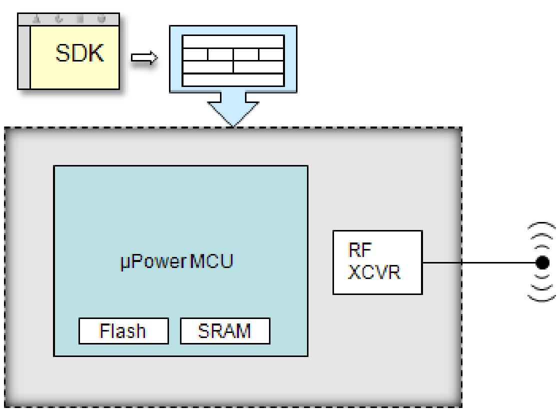
Discrete



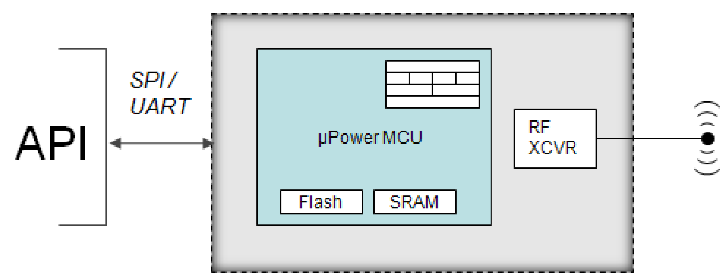
Radio-only module



Integrated module



Hostless module



The Internet of Things:
How To Ensure Your FPGA Designs Stay Relevant!

The Internet of Things: Ensure Your FPGA Designs Stay Relevant!

- IoT trend brings increased wireless connectivity
  Untethered, wireless connectivity is increasingly expected!
- Wireless modules make it easy to add this feature
- Plan for wireless connectivity from the outset!
- Wi-Fi or BT/BLE to Tablet or Smartphone facilitates quality user interfaces, diagnostic capabilities plus further options
- Equipment-, installation and maintenance costs can be reduced by eliminating cabling
- Flexibility, expandability and new use cases can be facilitated where cables are not practical

Next Steps

- Other X-Fest courses in this track:
  - *Making the IoT Smarter*
  - *Adding Smarter Vision to your Product with Zynq*
  - *Building Blocks for Enhancing User Interfaces*
- Access to these slides and more information
  - *Contact your local Avnet FAE*
  - *Downloads,etc available at www.xfest2014.com*
  - *Q&A forums for each course also available*
- Avnet Part Numbers:
  - ***AES-PMOD-WILINK8-G*** *(WiLink-8 Adaptor)*
  - ***AES-PMOD-MUWF-G*** *(SN8000 Pmod Wi-Fi module)*

Thank You

köszönöm
Kiitos
Asante
Shukria
Vinaka
Maake
Dhanyavadagalu
감사합니다
Dankscheen
спасибо
Kam Sah Hammida
اركش
Manana
Dankon
Terima Kasih
Matondo
Diolch i Chi
Dank Je
Mauruuru
Biyan
Taiku
Tack
Blagodaram
Ngiyabonga
Dziekuje
Chokrane
Grazie
Juspaxar
Arigato
Mochchakkeram
Gracias
Khap
Paldies
Tingki
நன்றி
Bedankt
D'akujem
धन्यवाद
cảm ơn bạn
Gratias Tibi
Ua Tsaug Rau Koj
Grazas
Di Ou Mèsi
Kia Ora
Kop Khun
Obrigado
Děkuji
Nirringrazzjak
ありがとう
Suksama
Nuwun
Rahmat
Matur
谢谢
хвала
Hvala
Welalin
Djiere Dieuf
Misaotra
Danke
Merci
Go Raibh Maith Agat
Tuke
Eskerrik Asko
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