

Embedded Linux on Zynq



김현옥 (hokim1972@naver.com)

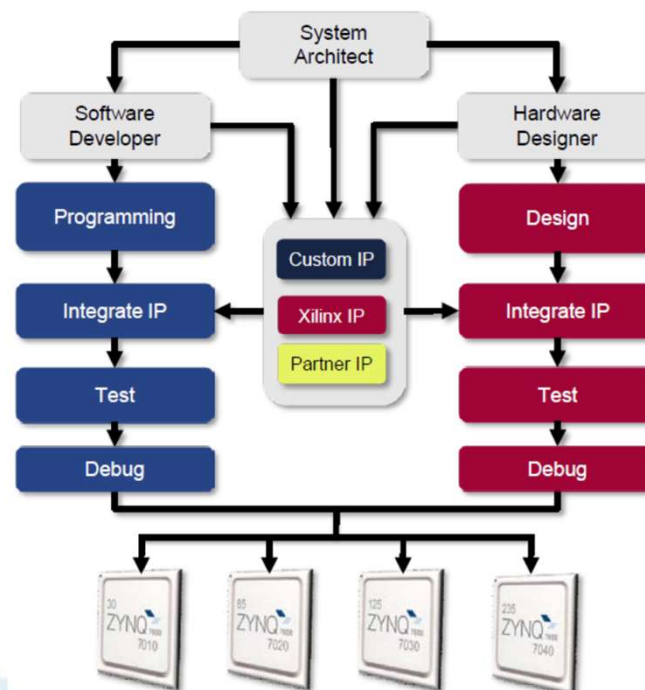
- Zynq = Dual core ARM (PS: Processing System) + FPGA (PL: Programmable Logic)

- Processor concentrated chip

Processor runs with minimal(?) PL programming.

Less flexibility.

More efficient parallel hardware and software development.



- **Bare-Metal** without OS

Possible to write fast programs.

Difficult to realize complex systems with components like webserver, FTP server, USB support and so on.

SDK Provides ARM Toolchain.

- **Real-Time OS**

For applications with strict time constraints.

Most are commercial.

- **Linux**

Greatest flexibility.

Many drivers, libraries and software package.



- **Vivado GUI, CUI(2015.4)**

Design hardware

Generate bit/hdf files

- **HSI Hardware Software Interface**

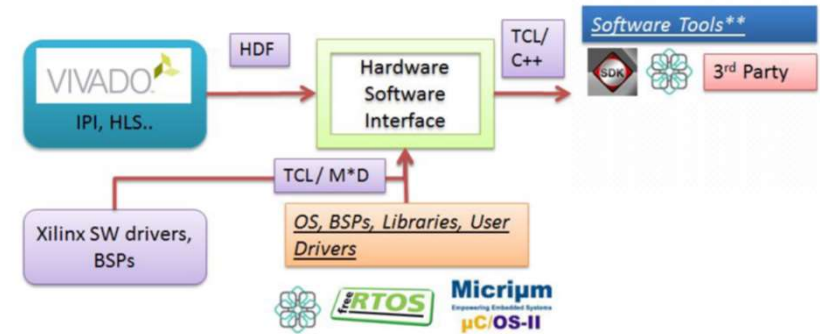
Scalable framework enabled SW tool integration with Vivado

Compile FSBL / Generate DT

- **Ubuntu (16.04 LTS)**

(Host) Compile u-boot, kernel and DT

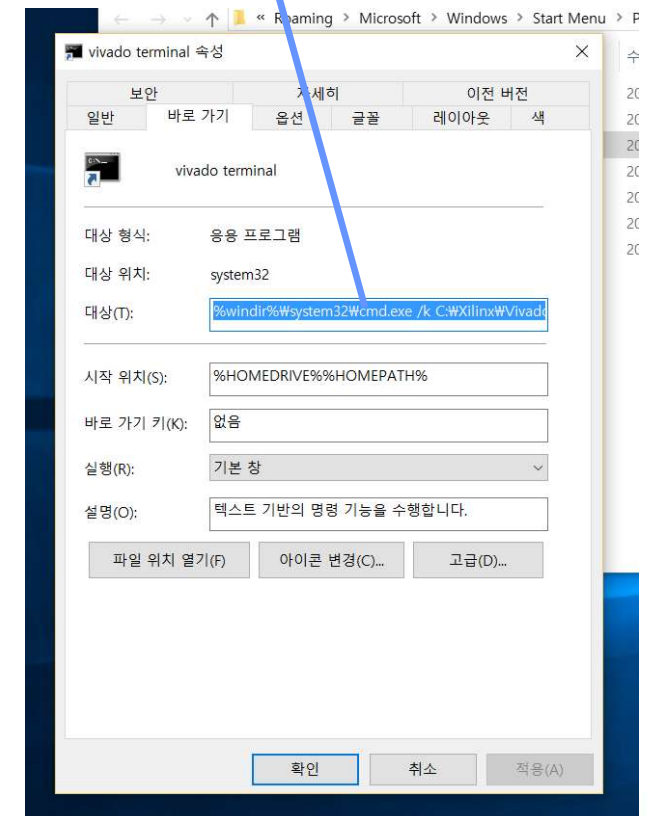
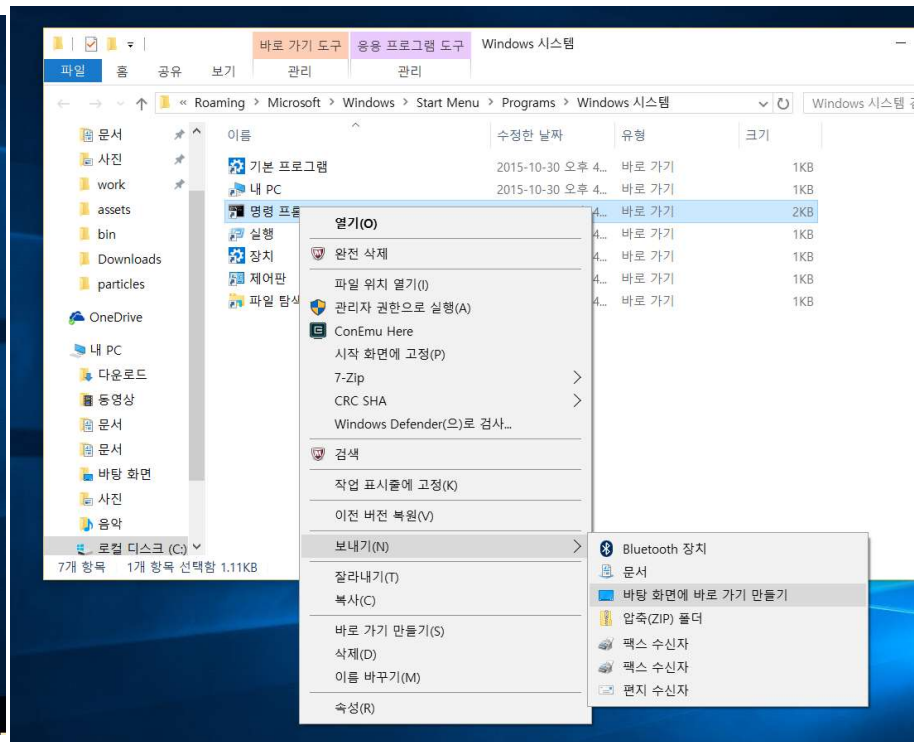
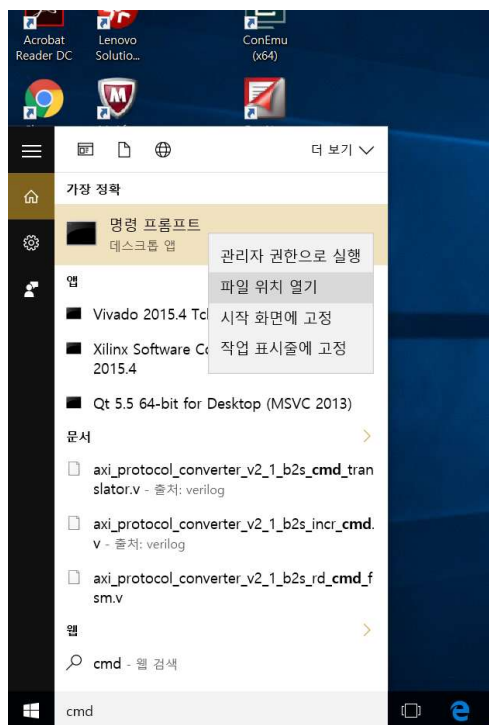
(Target) Compile drivers / applications



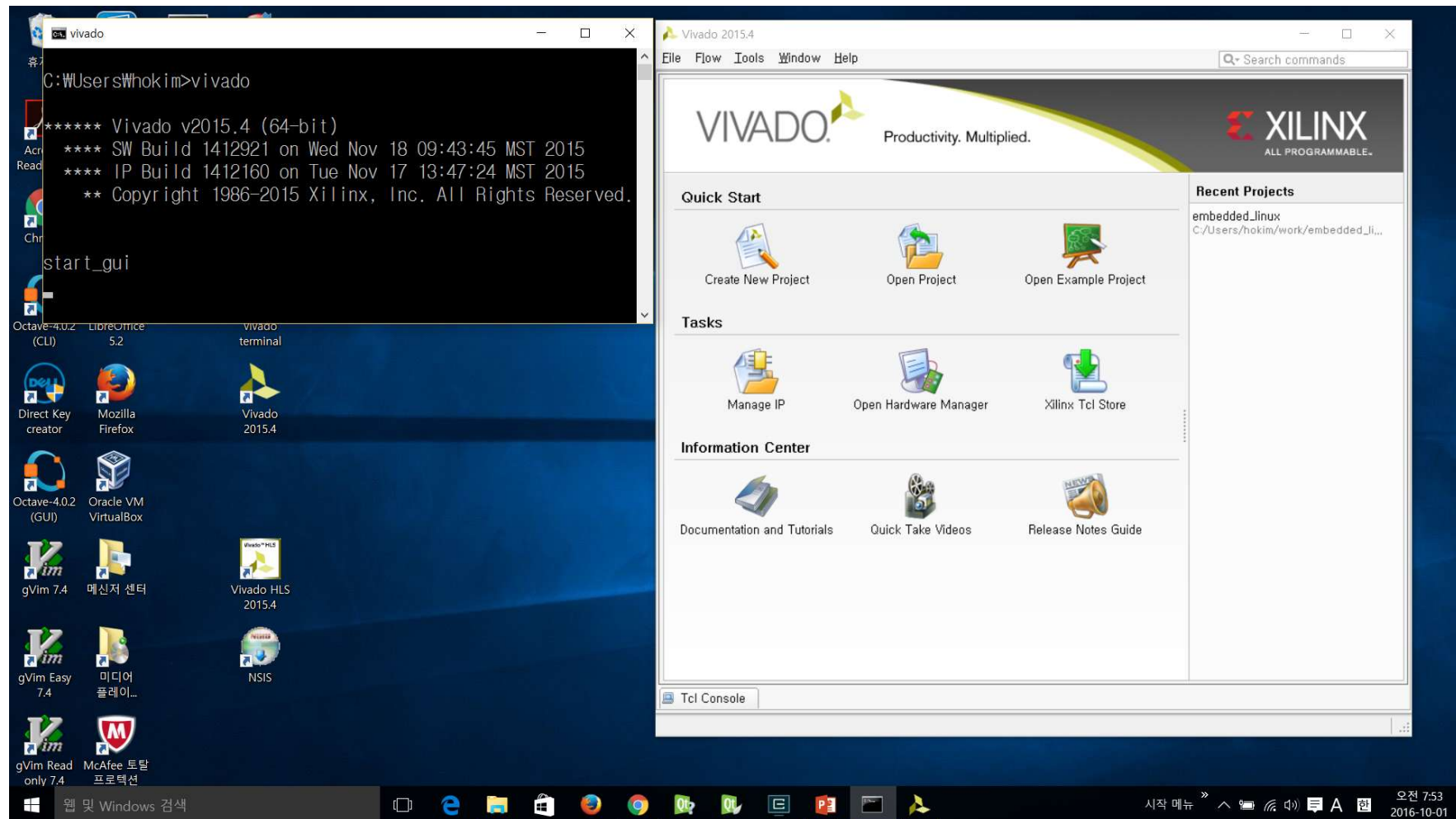
■ Windows 10

Install Vivado 2015.4 w/ SDK.
cmd terminal for Vivado.

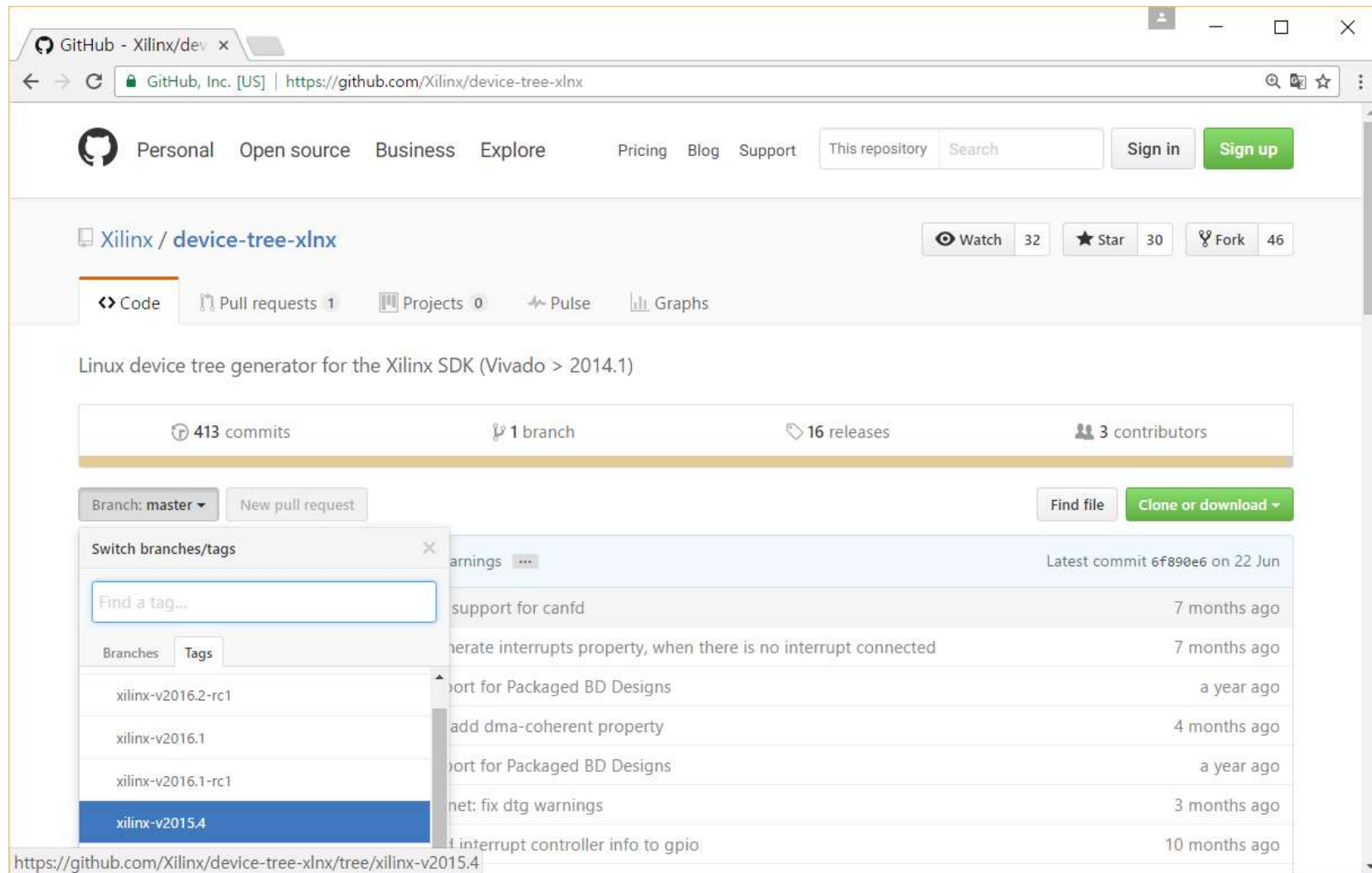
`%windir%\system32\cmd.exe /k C:\Xilinx\Vivado\2015.4\settings64.bat`



- **cmd terminal** for Vivado.



■ Device Tree Source



GitHub - Xilinx/dev x

GitHub, Inc. [US] | <https://github.com/Xilinx/device-tree-xlnx>

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Xilinx / device-tree-xlnx

Watch 32 Star 30 Fork 46

Code Pull requests 1 Projects 0 Pulse Graphs

Linux device tree generator for the Xilinx SDK (Vivado > 2014.1)

413 commits 1 branch 16 releases 3 contributors

Branch: master New pull request Find file Clone or download

Switch branches/tags

Find a tag...

Branches Tags

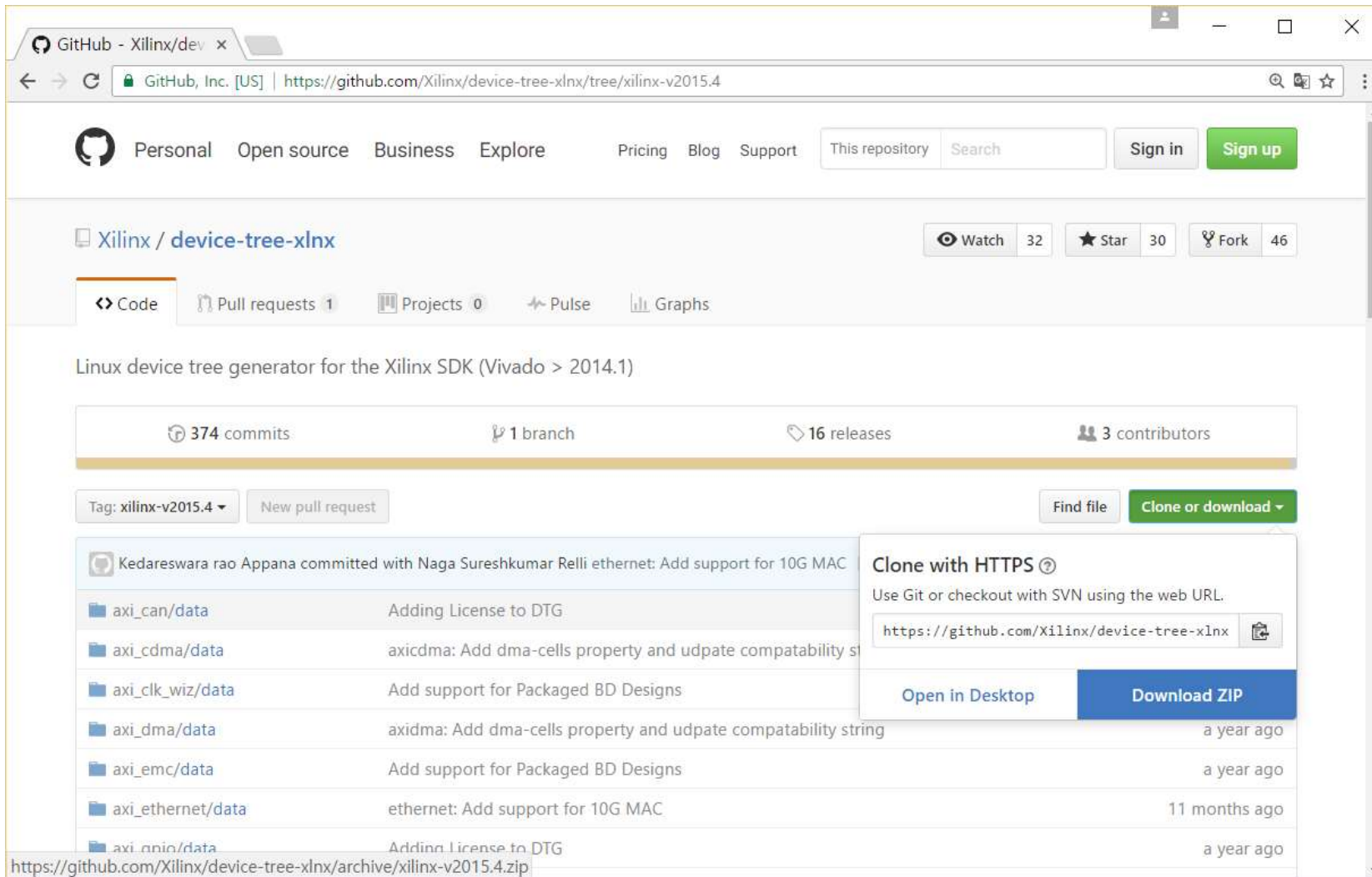
- xilinx-v2016.2-rc1
- xilinx-v2016.1
- xilinx-v2016.1-rc1
- xilinx-v2015.4**

Latest commit 6f890e6 on 22 Jun

- support for canfd 7 months ago
- generate interrupts property, when there is no interrupt connected 7 months ago
- support for Packaged BD Designs a year ago
- add dma-coherent property 4 months ago
- support for Packaged BD Designs a year ago
- net: fix dtg warnings 3 months ago
- add interrupt controller info to gpio 10 months ago

<https://github.com/Xilinx/device-tree-xlnx/tree/xilinx-v2015.4>

■ Device Tree Source



GitHub - Xilinx/dev x

GitHub, Inc. [US] | <https://github.com/Xilinx/device-tree-xlnx/tree/xilinx-v2015.4>

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Xilinx / **device-tree-xlnx** Watch 32 Star 30 Fork 46

Code Pull requests 1 Projects 0 Pulse Graphs

Linux device tree generator for the Xilinx SDK (Vivado > 2014.1)

374 commits 1 branch 16 releases 3 contributors

Tag: xilinx-v2015.4 New pull request Find file Clone or download

Kedareswara rao Appana committed with Naga Sureshkumar Relli ethernet: Add support for 10G MAC

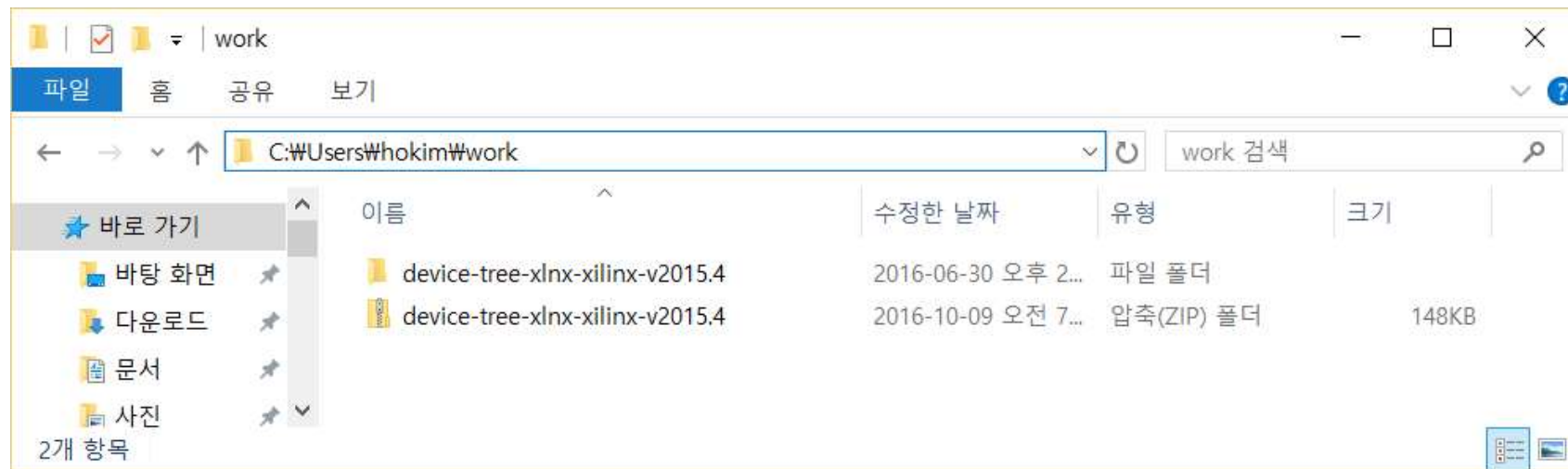
axi_can/data	Adding License to DTG	
axi_cdma/data	axicdma: Add dma-cells property and update compatability string	
axi_clk_wiz/data	Add support for Packaged BD Designs	
axi_dma/data	axidma: Add dma-cells property and update compatability string	a year ago
axi_emc/data	Add support for Packaged BD Designs	a year ago
axi_ethernet/data	ethernet: Add support for 10G MAC	11 months ago
axi_nnino/data	Adding License to DTG	a year ago

<https://github.com/Xilinx/device-tree-xlnx/archive/xilinx-v2015.4.zip>

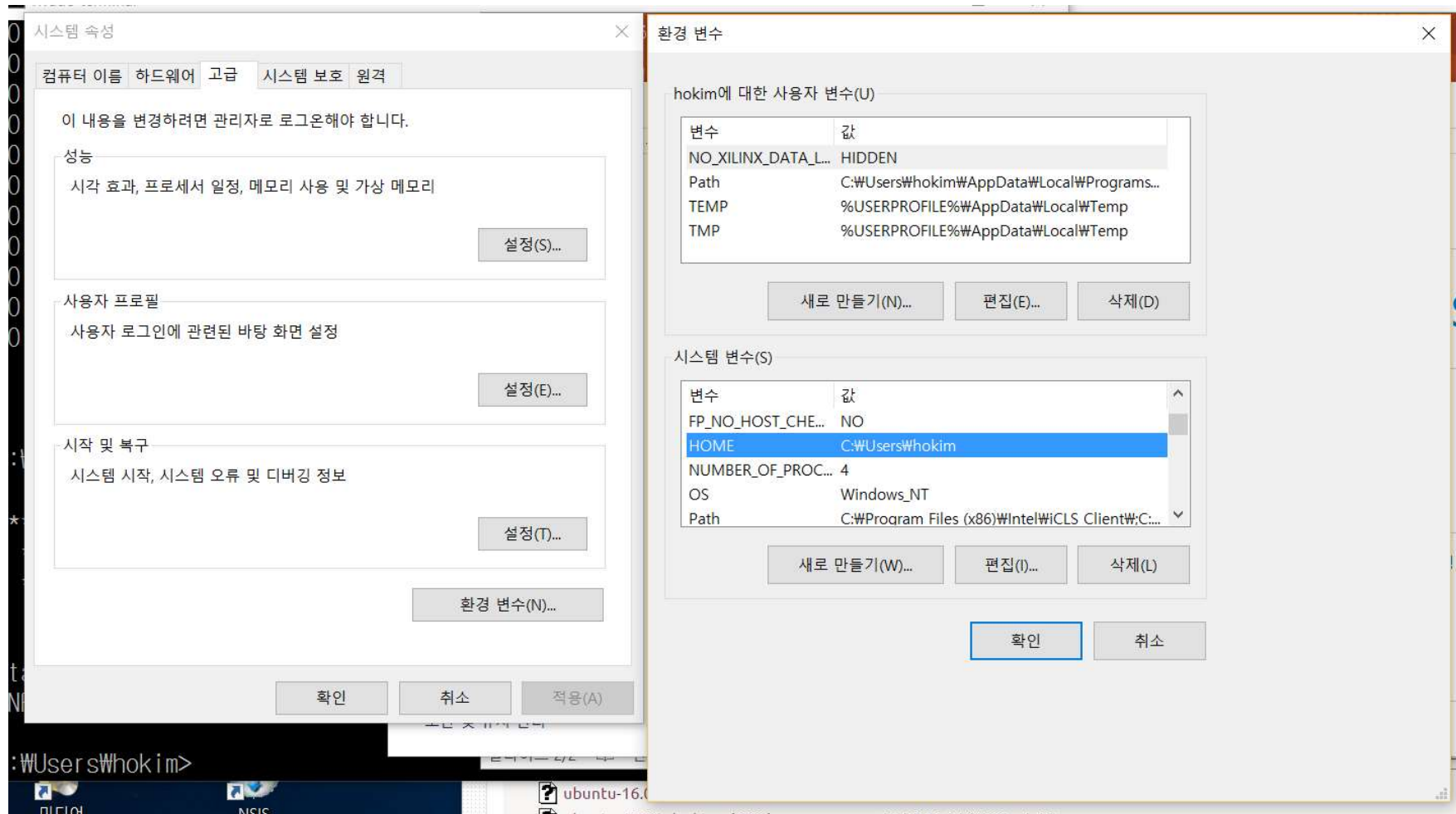
Clone with HTTPS ?
Use Git or checkout with SVN using the web URL.
<https://github.com/Xilinx/device-tree-xlnx>

Open in Desktop Download ZIP

■ Device Tree Source



■ Environment Variable(HOME)



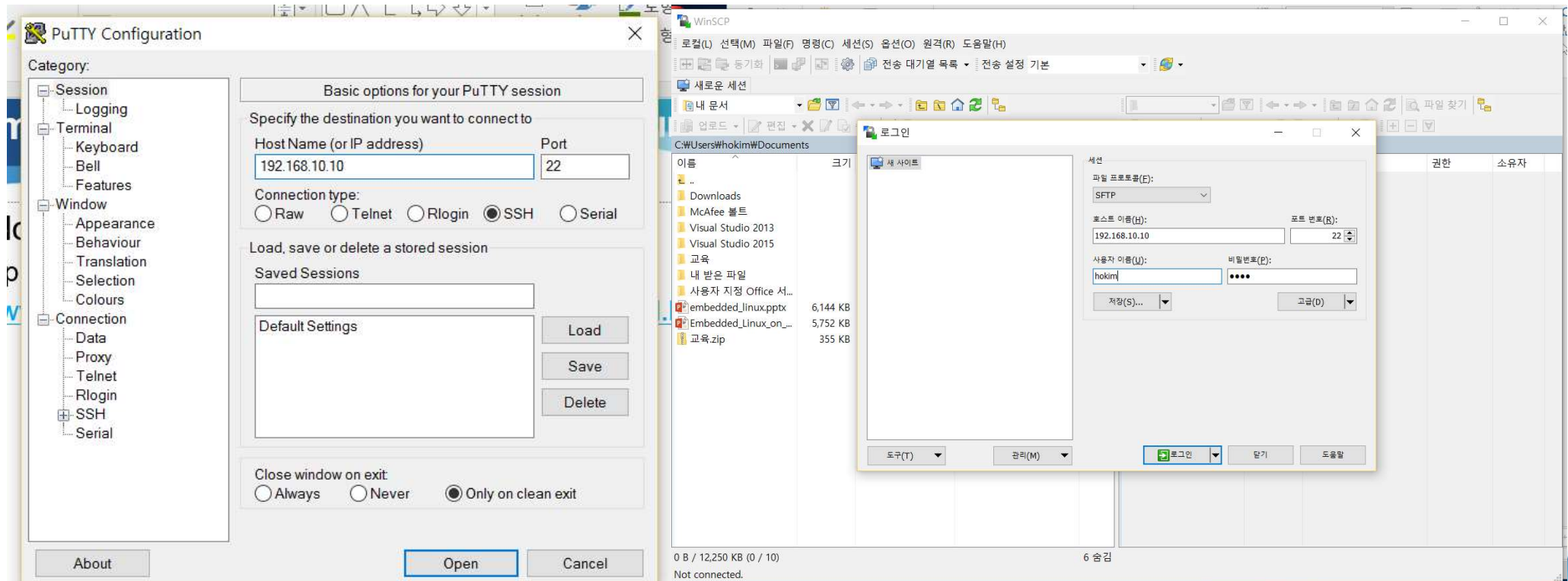
■ Windows ↔ Ubuntu

Install putty.exe for remote login shell.

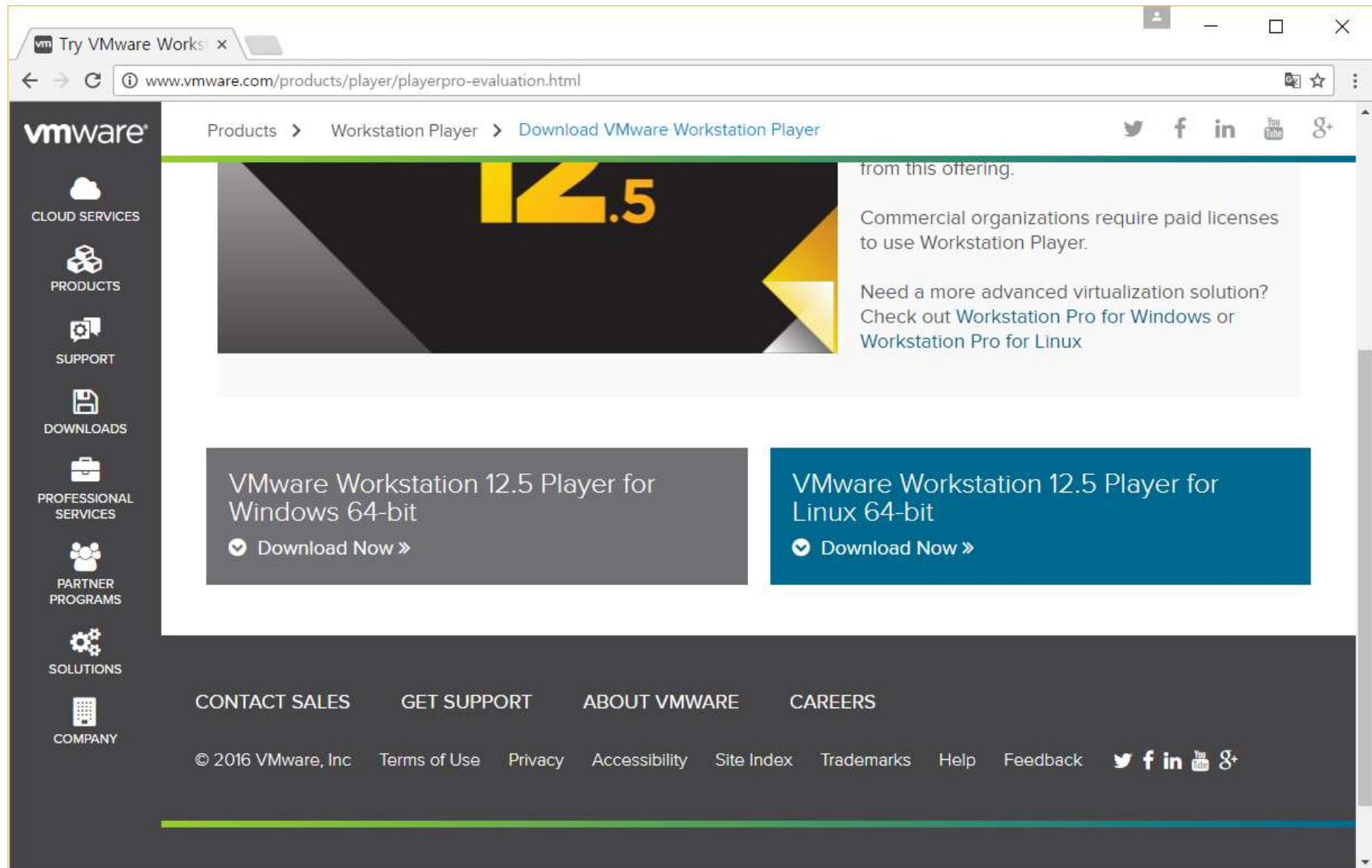
(<http://www.chiark.greenend.org.uk/~sgtatham/putty/download.html>)

Install WinSCP for file transfer.

(<https://winscp.net/eng/download.php>)



■ Ubuntu on VMware-player



The screenshot shows the VMware Workstation 12.5 Player download page. The browser address bar displays www.vmware.com/products/player/playerpro-evaluation.html. The page features a dark sidebar with navigation links: CLOUD SERVICES, PRODUCTS, SUPPORT, DOWNLOADS, PROFESSIONAL SERVICES, PARTNER PROGRAMS, SOLUTIONS, and COMPANY. The main content area includes a large banner for VMware Workstation 12.5 Player, a note about commercial licenses, and two download buttons: "VMware Workstation 12.5 Player for Windows 64-bit" and "VMware Workstation 12.5 Player for Linux 64-bit". The footer contains links for CONTACT SALES, GET SUPPORT, ABOUT VMWARE, and CAREERS, along with copyright information and social media icons.

vmware Try VMware Workstation x

www.vmware.com/products/player/playerpro-evaluation.html

Products > Workstation Player > Download VMware Workstation Player

12.5

from this offering.

Commercial organizations require paid licenses to use Workstation Player.

Need a more advanced virtualization solution? Check out [Workstation Pro for Windows](#) or [Workstation Pro for Linux](#)

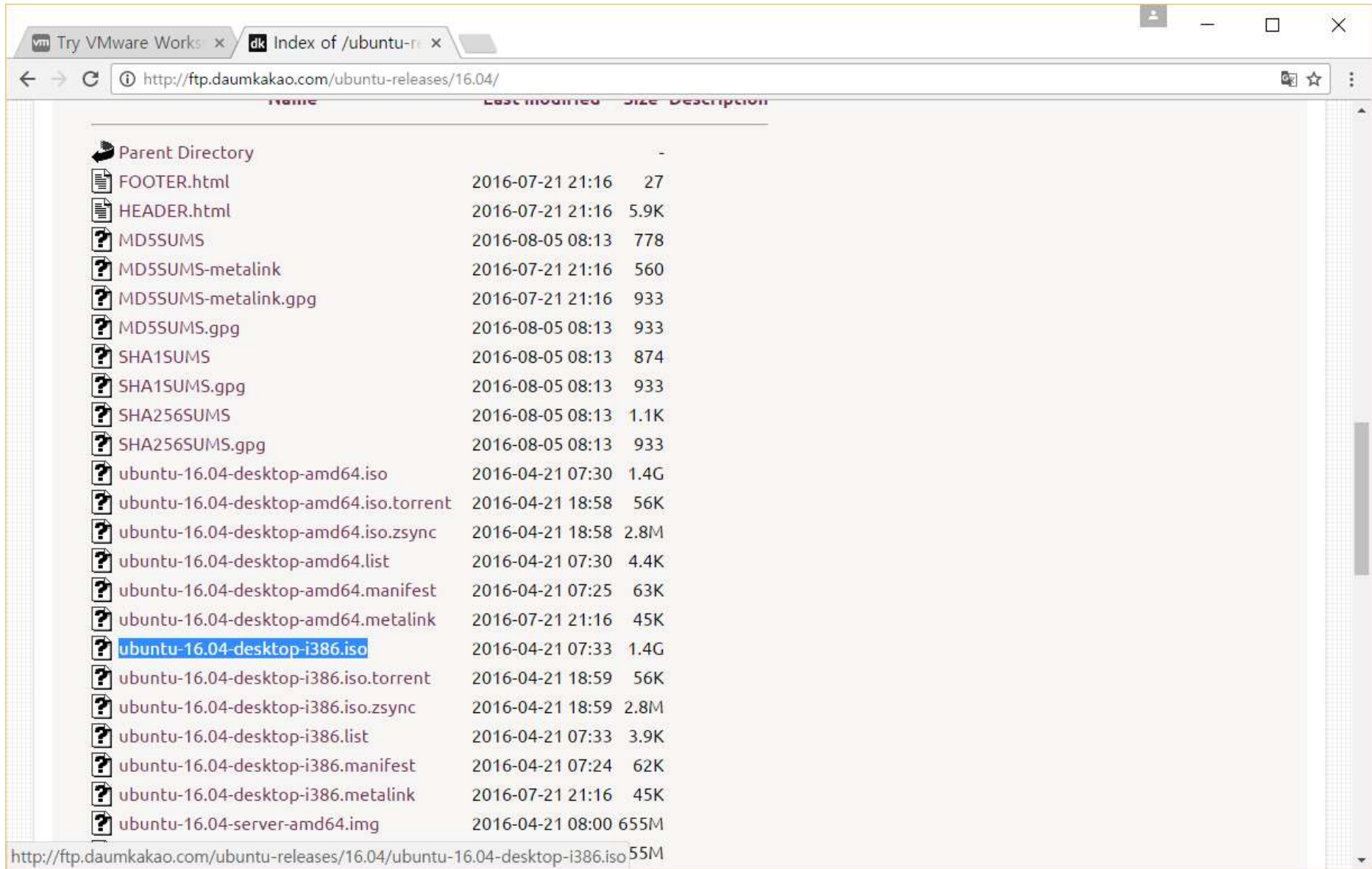
VMware Workstation 12.5 Player for Windows 64-bit
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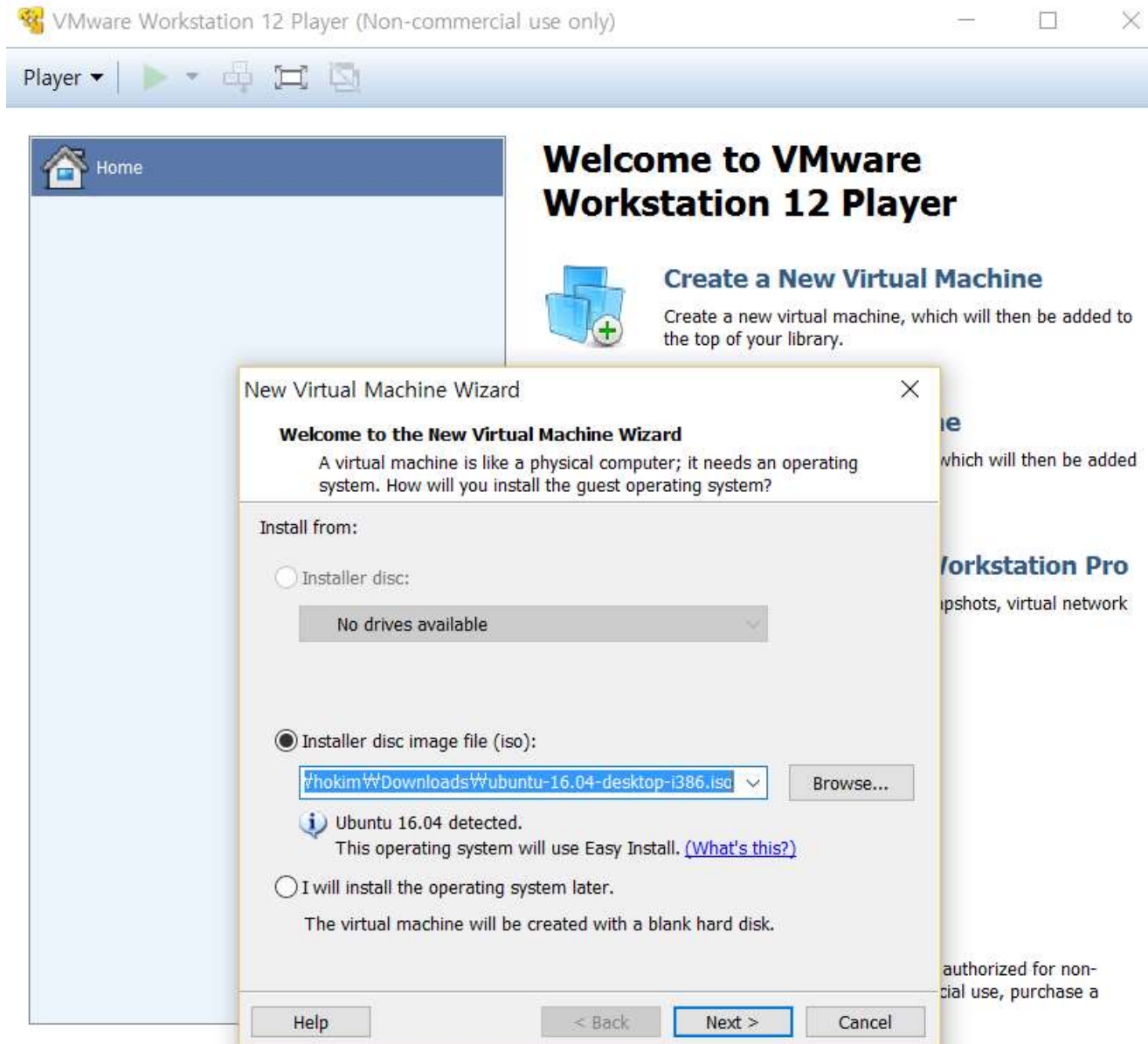
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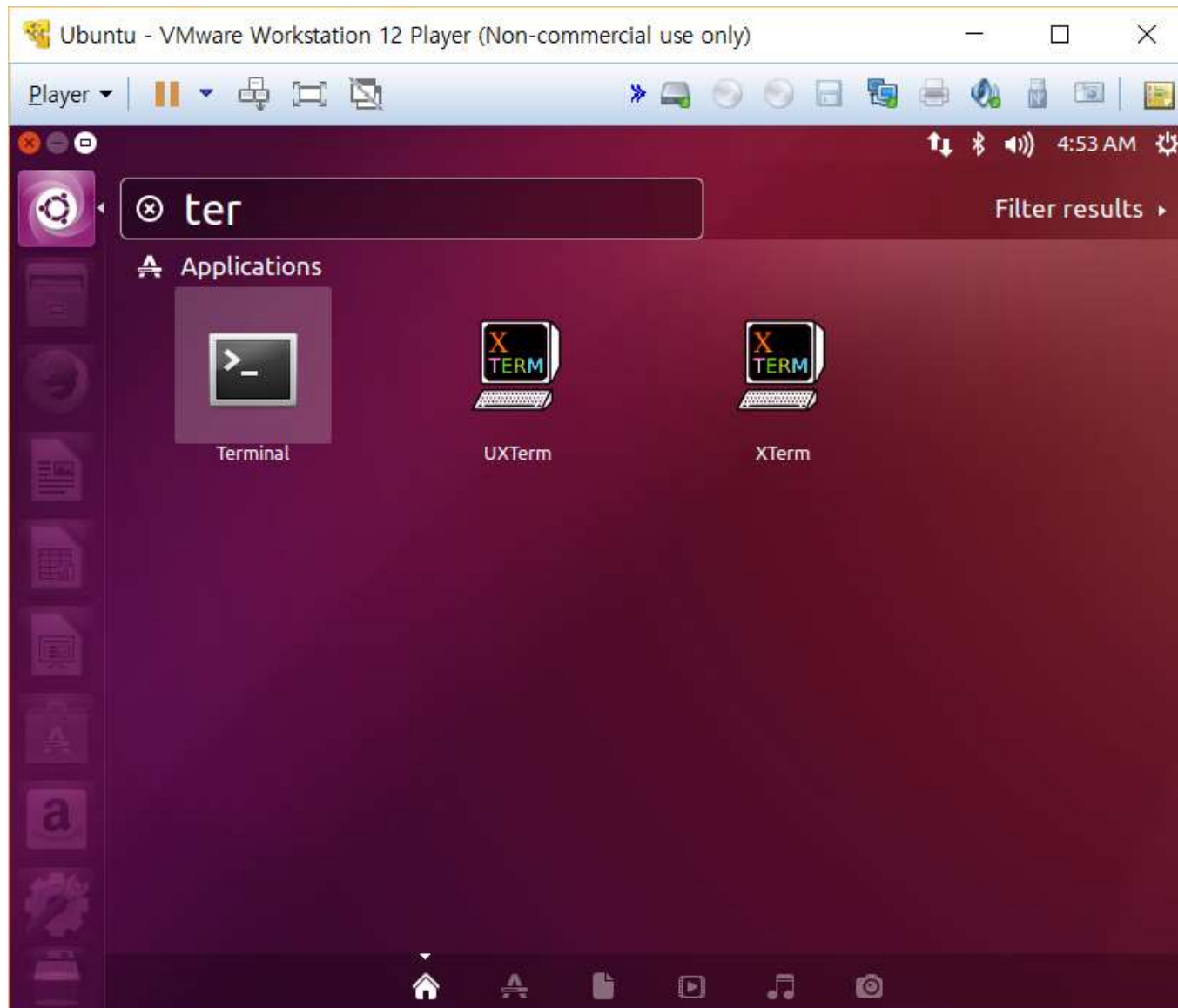
■ Ubuntu on VMware-player



■ Ubuntu on VMware-player

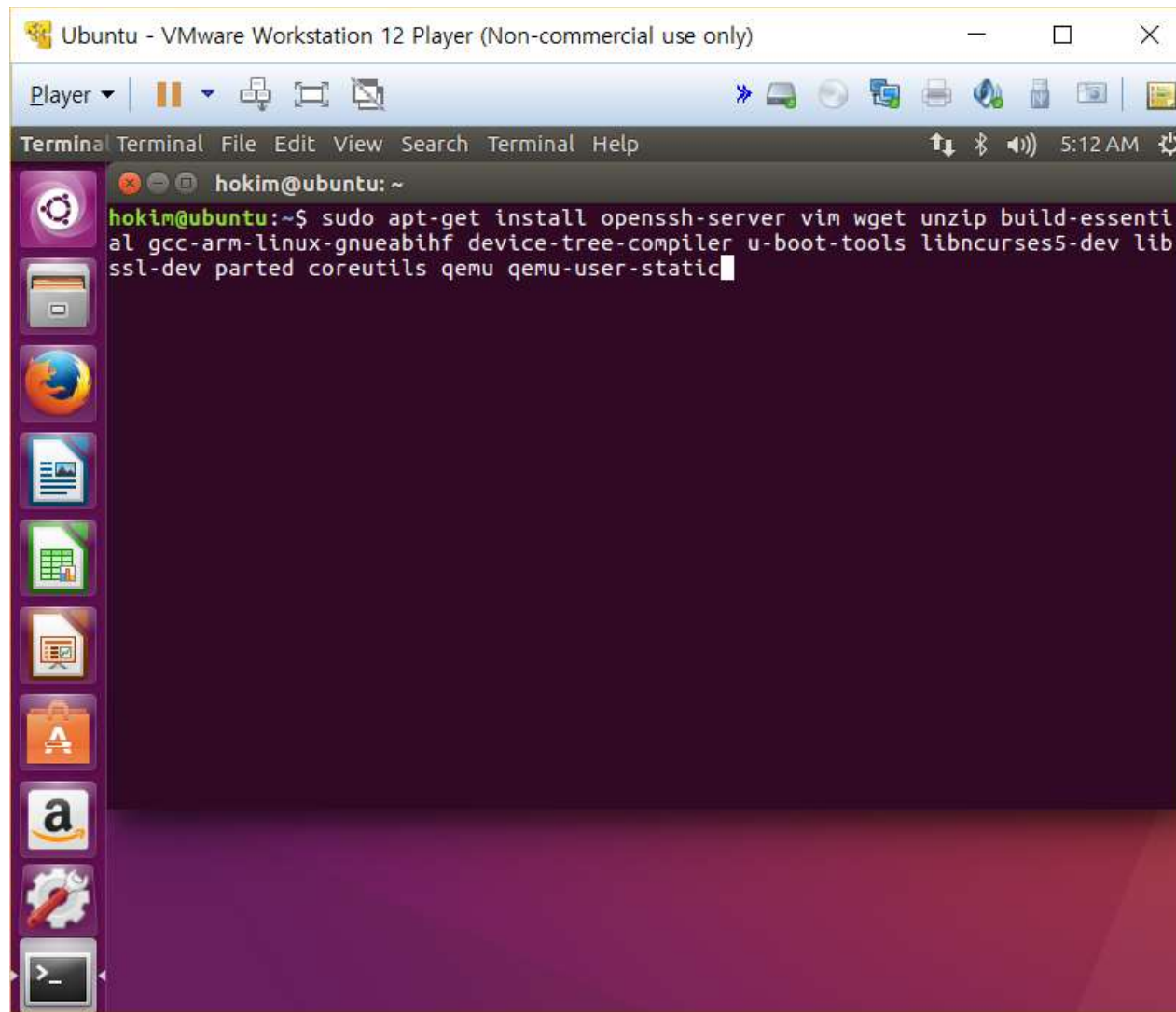


■ Ubuntu on VMware-player



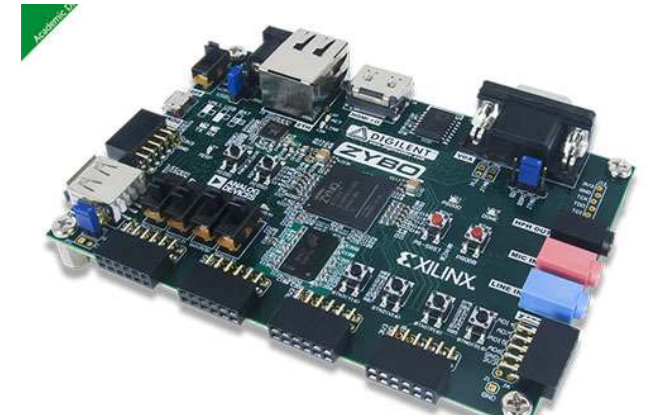
■ Ubuntu on VMware-player

```
$ sudo apt-get install openssh-server vim wget unzip build-essential gcc-arm-linux-gnueabi device-tree-compiler u-boot-tools libncurses5-dev libssl-dev parted coreutils qemu qemu-user-static
```



■ Target Board Zybo(Zynq-7010)

Gigabit Ethernet, USB, SD, UART
28,000 logic cells, 240 KB BRAM



■ Development Process

1. bit stream

2. FSBL

3. DT Generation

4. u-boot

5. DT Compile

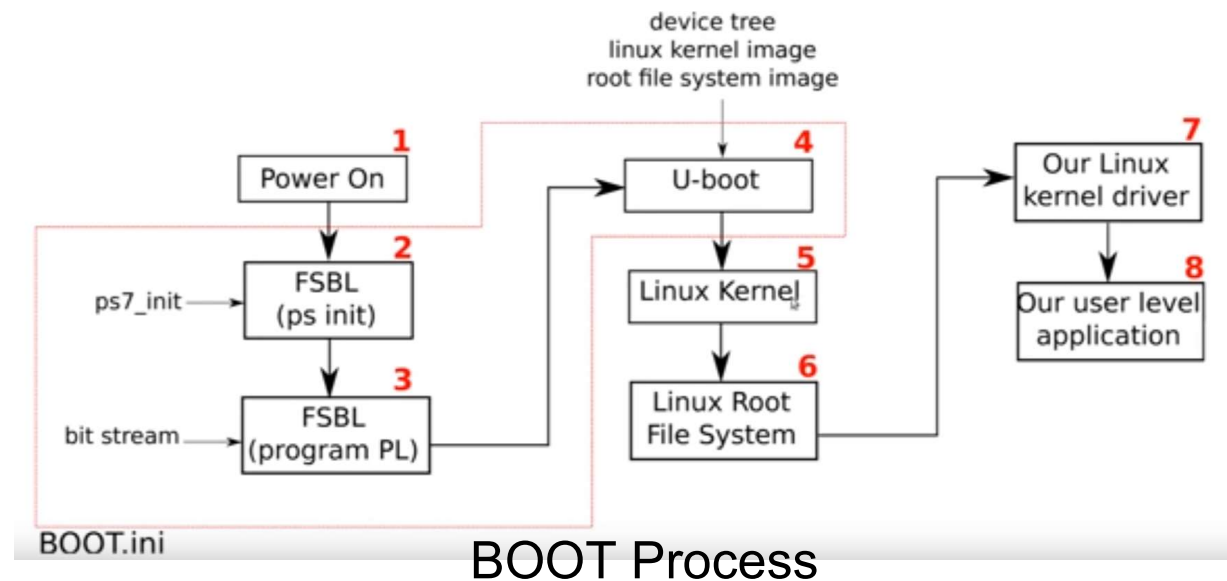
6. linux kernel image

7. root file system image

8. BOOT.bin(fsbl + bit + u-boot)

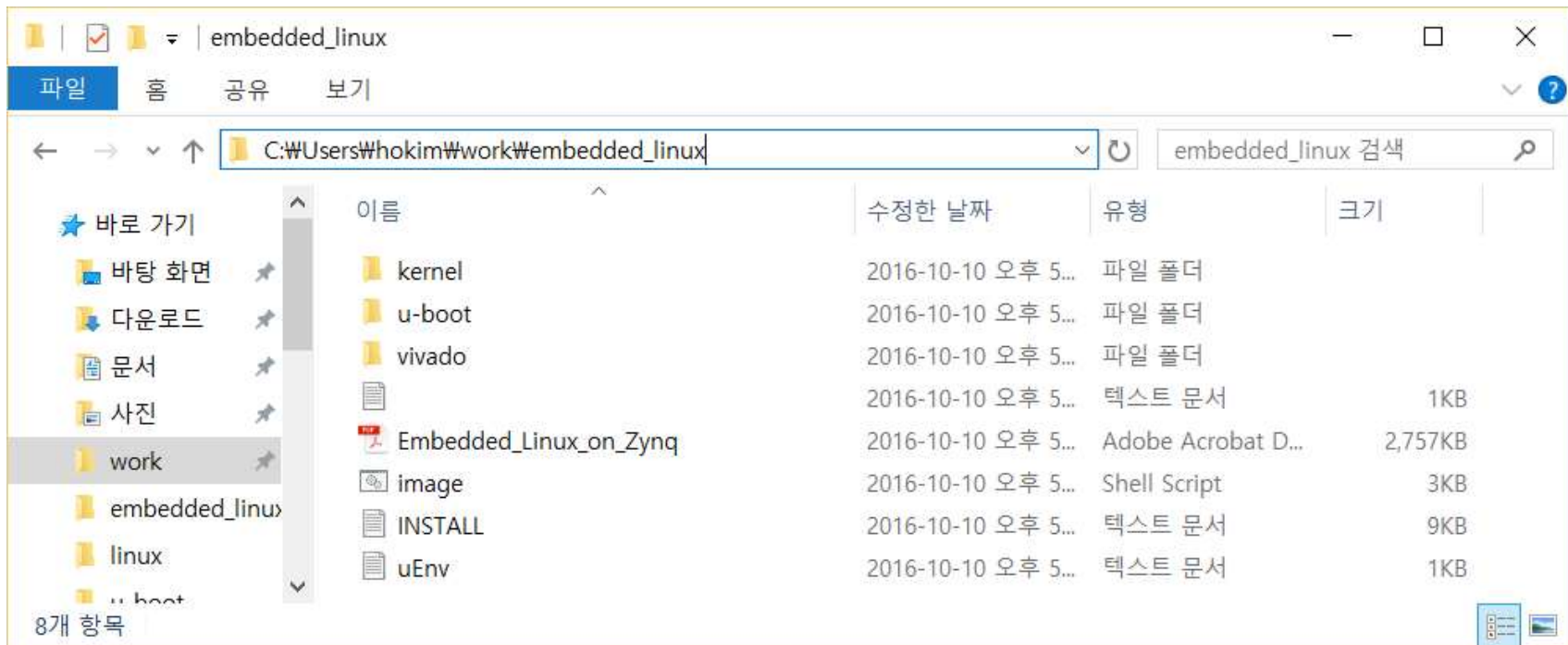
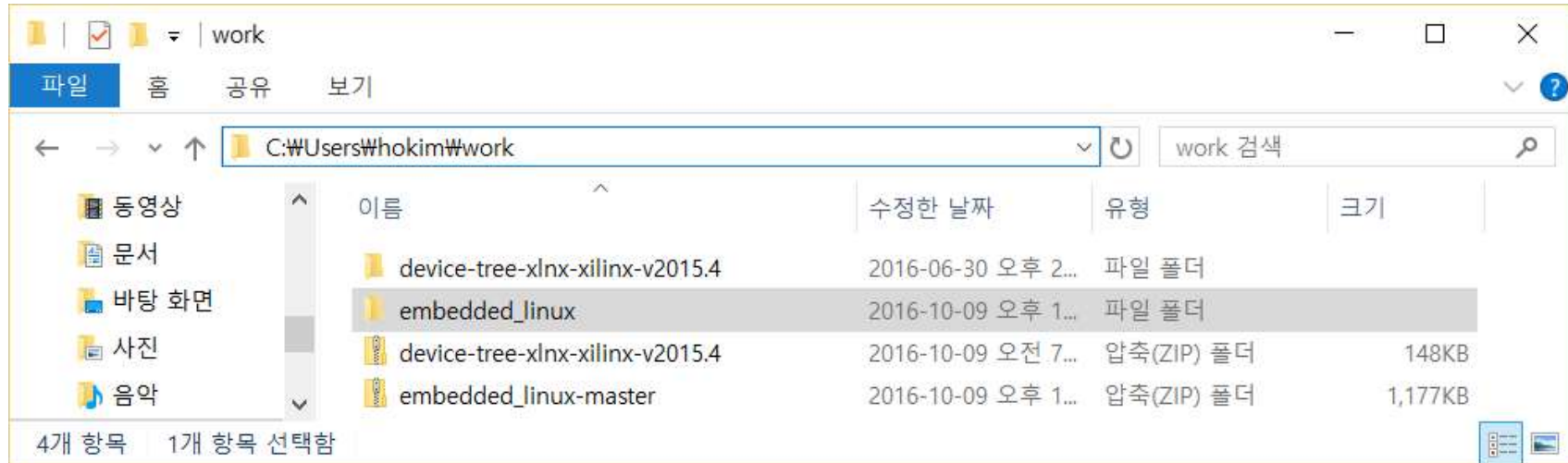
9. Update BOOT.bin / DT / kernel

10. (user kernel driver)/user application



■ Source code

https://github.com/inipro/embedded_linux



■ Vivado Design

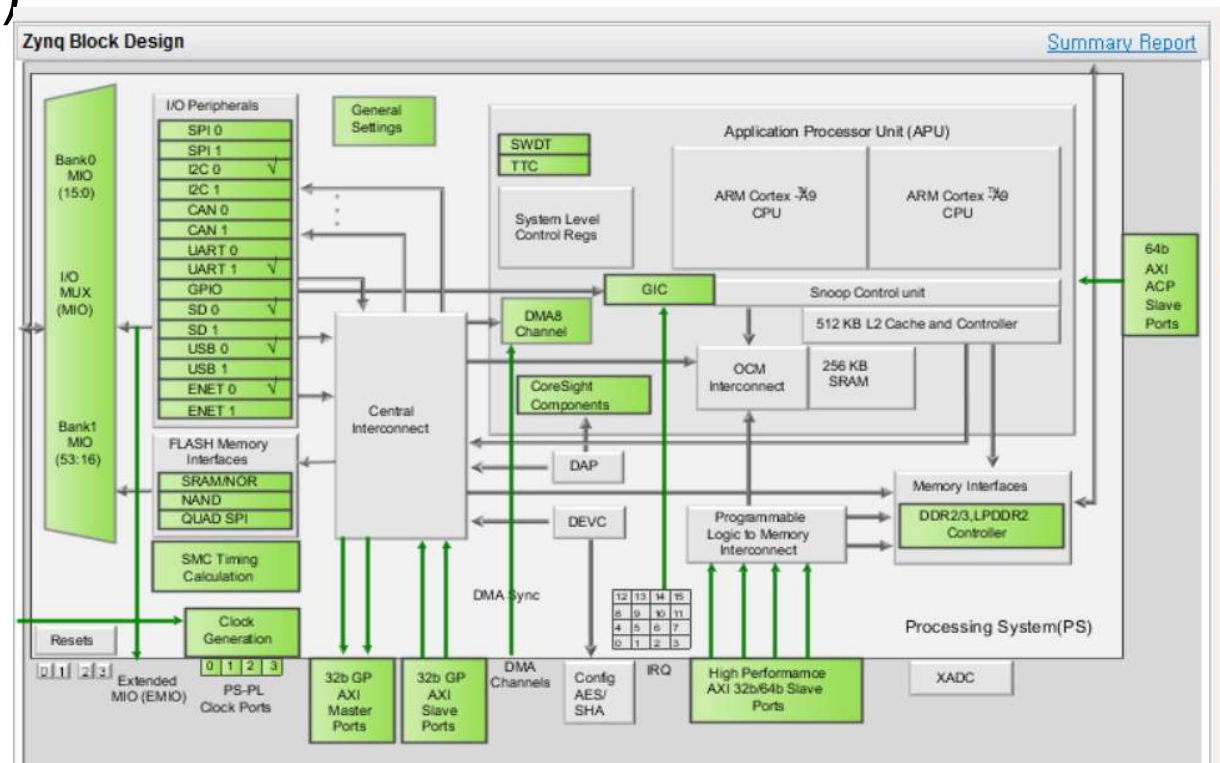
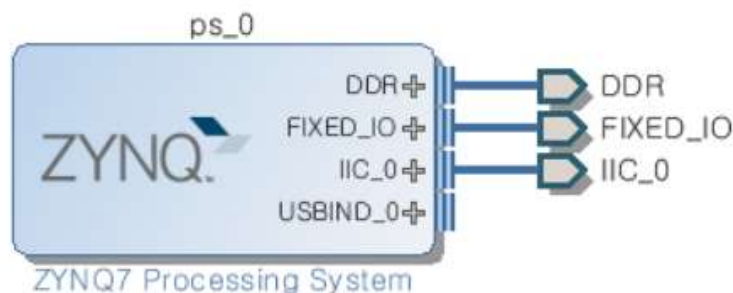
SD0 (boot files, root file system)

UART1 (console)

I2C0 (eeprom w/ Ethernet mac address; EMIO)

USB0 (usb host)

ENET0 (Gigabit Ethernet)



embedded_linux.tcl

```
set project_name embedded_linux
set part_name xc7z010clg400-1
#set ip_dir ip
set bd_path $project_name/$project_name.srsrcs/sources_1/bd/system
file delete -force $project_name
create_project -part $part_name $project_name $project_name
#set_property ip_repo_paths $ip_dir [current_project]
#update_ip_catalog
create_bd_design system

create_bd_cell -type ip -vlnv xilinx.com:ip:processing_system7:5.5 ps_0
source embedded_linux_preset.tcl
set_property -dict [apply_preset IPINST] [get_bd_cells ps_0]
apply_bd_automation -rule xilinx.com:bd_rule:processing_system7 -config {
    make_external {FIXED_IO, DDR}
} [get_bd_cells ps_0]
create_bd_intf_port -mode Master -vlnv xilinx.com:interface:iic_rtl:1.0 IIC_0
connect_bd_intf_net [get_bd_intf_pins ps_0/IIC_0] [get_bd_intf_ports IIC_0]

generate_target all [get_files $bd_path/system.bd]
make_wrapper -files [get_files $bd_path/system.bd] -top
add_files -norecurse $bd_path/hdl/system_wrapper.v
add_files -norecurse -fileset constrs_1 zybo.xdc
set_property verilog_define {TOOL_VIVADO} [current_fileset]
close_project
```

In cmd window for Vivado

```
C:\ cd C:\Users\hokim\work\embedded_linux\vivado
C:\ vivado -nolog -nojournal -mode batch -source embedded_linux.tcl
```

output : embedded_linux\embedded_linux.xpr...



Bit Generation

The screenshot displays the Vivado 2015.4 IDE interface for a project named 'embedded_linux'. The top menu bar includes File, Edit, Flow, Tools, Window, Layout, View, and Help. The toolbar shows various icons for file operations and simulation. The left sidebar contains the Flow Navigator, which lists the following steps: Simulation (Simulation Settings, Run Simulation), RTL Analysis (Elaboration Settings, Open Elaborated Design), Synthesis (Synthesis Settings, Run Synthesis, Open Synthesized Design), Implementation (Implementation Settings, Run Implementation, Open Implemented Design), and Program and Debug (Bitstream Settings, **Generate Bitstream**, Open Hardware Manager). The 'Generate Bitstream' option is highlighted with a red rectangle.

The main workspace is divided into several panes. The 'Block Design' pane shows a hierarchical view of the design, including 'system', 'External Interfaces', 'Interface Connections', and 'ps_0 (ZYNQ7 Processing System:5,5)'. The 'Diagram' pane displays a block diagram of the 'ps_0' component, which is a ZYNQ7 Processing System. It shows connections to DDR, FIXED_IO, IIC_0, and USBIND_0. The 'Tcl Console' pane at the bottom shows the following log messages:

```
Adding component instance block -- xilinx.com:ip:processing_system7:5.5 - ps_0
Successfully read diagram <system> from BD file <C:/Users/hokim/work/embedded_linux/vivado/embedded_linux/srcs/sources_1/bd/system/s
open_bd_design: Time (s): cpu = 00:00:14 ; elapsed = 00:00:11 . Memory (MB): peak = 877.746 ; gain = 106.148
```

The status bar at the bottom indicates 'Generate a programming file after implementation'.

hwdef.tcl

```
# vivado -nolog -nojournal -mode batch -source hwdef.tcl

set project_name embedded_linux

open_project $project_name/$project_name.xpr

if {[get_property PROGRESS [get_runs synth_1]] != "100%"} {
    launch_runs synth_1
    wait_on_run synth_1
}

file delete -force $project_name/$project_name.hwdef

write_hwdef -force -file $project_name/$project_name.hwdef

close_project
```

```
C:\ vivado -nolog -nojournal -mode batch -source hwdef.tcl
```

```
output : embedded_linux\embedded_linux.hwdef
```



fsbl.tcl

```
# hsi -nolog -nojournal -mode batch -source fsbl.tcl

set project_name embedded_linux

set hard_path $project_name/$project_name.hard
set fsbl_path $project_name/$project_name.fsbl

file delete -force $hard_path $fsbl_path

file mkdir $hard_path
file copy -force $project_name/$project_name.hwdef $hard_path/$project_name.hdf

open_hw_design $hard_path/$project_name.hdf
create_sw_design -proc ps7_cortexa9_0 -os standalone fsbl

add_library xilffs
add_library xilrsa

generate_app -proc ps7_cortexa9_0 -app zynq_fsbl -dir $fsbl_path -compile

close_hw_design [current_hw_design]
```

```
C:\ hsi -nolog -nojournal -mode batch -source fsbl.tcl
```

output : embedded_linux\embedded_linux.fsbl\executable.elf



devicetree.tcl

```
# hsi -nolog -nojournal -mode batch -source devicetree.tcl

set project_name embedded_linux

set boot_args {console=ttyPS0,115200 root=/dev/mmcblk0p2 ro rootfstype=ext4 earlyprintk rootwait}

set hard_path $project_name/$project_name.hard
set tree_path $project_name/$project_name.tree

file delete -force $hard_path $tree_path

file mkdir $hard_path
file copy -force $project_name/$project_name.hwdef $hard_path/$project_name.hdf

set_repo_path $::env(HOME)/work/device-tree-xlnx-xilinx-v2015.4

open_hw_design $hard_path/$project_name.hdf
create_sw_design -proc ps7_cortexa9_0 -os device_tree devicetree

set_property CONFIG.kernel_version {2015.4} [get_os]
set_property CONFIG.bootargs $boot_args [get_os]

generate_bsp -dir $tree_path

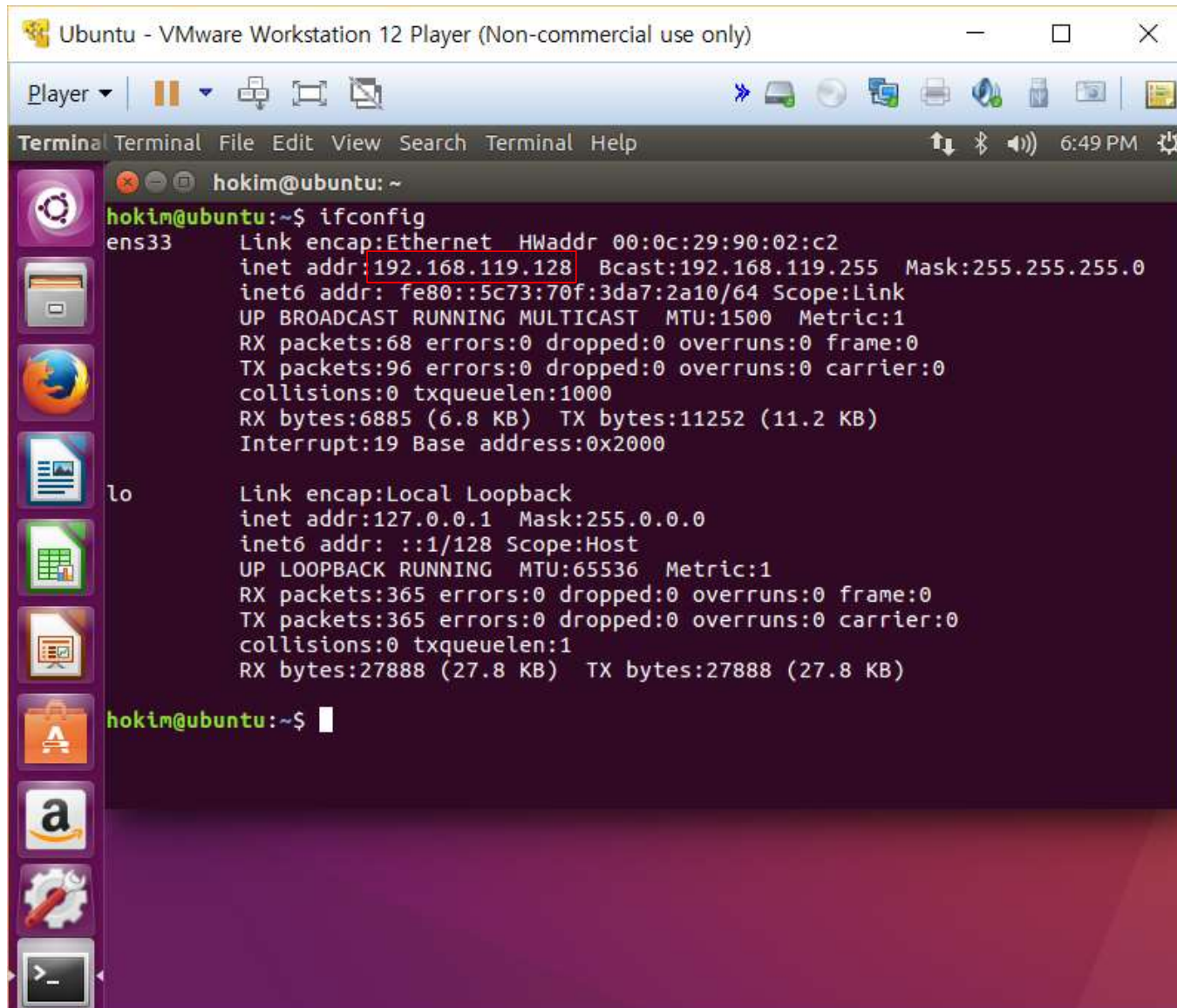
close_sw_design [current_sw_design]
close_hw_design [current_hw_design]
```

```
C:\ hsi -nolog -nojournal -mode batch -source devicetree.tcl
```

```
output : embedded_linux\embedded_linux.tree/*
```

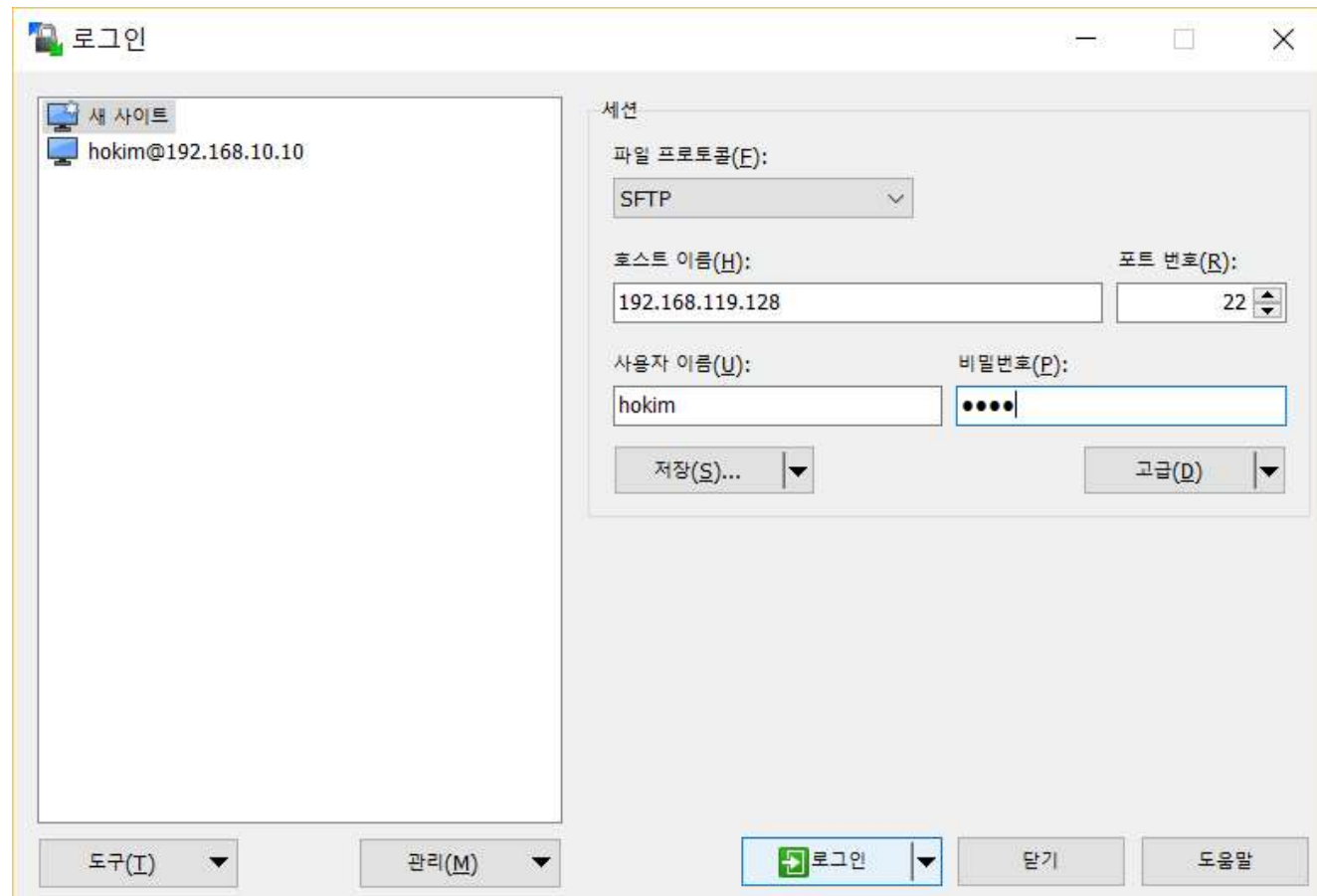


Ubuntu network IP

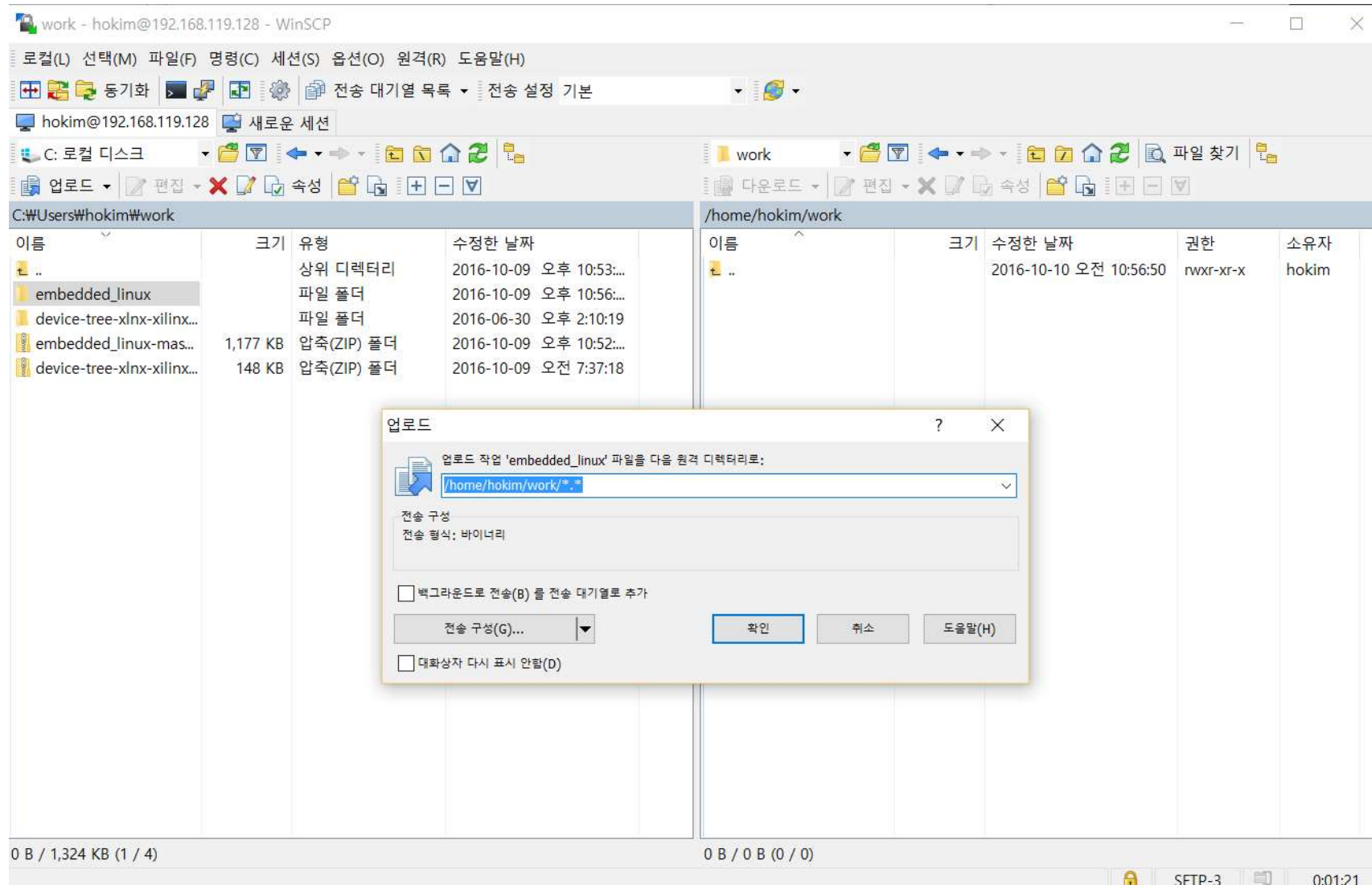


```
hokim@ubuntu: ~  
hokim@ubuntu:~$ ifconfig  
ens33  Link encap:Ethernet  HWaddr 00:0c:29:90:02:c2  
        inet addr:192.168.119.128  Bcast:192.168.119.255  Mask:255.255.255.0  
        inet6 addr: fe80::5c73:70f:3da7:2a10/64 Scope:Link  
        UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1  
        RX packets:68 errors:0 dropped:0 overruns:0 frame:0  
        TX packets:96 errors:0 dropped:0 overruns:0 carrier:0  
        collisions:0 txqueuelen:1000  
        RX bytes:6885 (6.8 KB)  TX bytes:11252 (11.2 KB)  
        Interrupt:19 Base address:0x2000  
  
lo      Link encap:Local Loopback  
        inet addr:127.0.0.1  Mask:255.0.0.0  
        inet6 addr: ::1/128 Scope:Host  
        UP LOOPBACK RUNNING  MTU:65536  Metric:1  
        RX packets:365 errors:0 dropped:0 overruns:0 frame:0  
        TX packets:365 errors:0 dropped:0 overruns:0 carrier:0  
        collisions:0 txqueuelen:1  
        RX bytes:27888 (27.8 KB)  TX bytes:27888 (27.8 KB)  
  
hokim@ubuntu:~$
```

embedded_linux using WinSCP



embedded_linux using WinSCP



- **Boot loader for linux**

Load linux kernel(ulmage, devicetree.dtb) from SD to DRAM.

Set ethernet using mac address from i2c eeprom.

Boot ulmage.



In Terminal of Ubuntu

Can use gedit instead of vi

- : deletion

+ : insert

```
$ cd ~/work/embedded_linux
$ mkdir -p dl
$ wget https://github.com/Xilinx/u-boot-xlnx/archive/xilinx-
v2015.4.tar.gz -O dl/u-boot-xlnx-xilinx-v2015.4.tar.gz
$ cd u-boot
$ tar xvzf ../dl/u-boot-xlnx-xilinx-v2015.4.tar.gz
$ cd u-boot-xlnx-xilinx-v2015.4
$ vi board/xilinx/zynq/board.c
```



board/Xilinx/zynq/board.c

```
int board_late_init(void)
{
+  #if defined(CONFIG_ZYNQ_GEM_EEPROM_ADDR) && \
+    defined(CONFIG_ZYNQ_GEM_I2C_MAC_OFFSET)
+    unsigned char enetaddr[6];
+
+    if (eeprom_read(CONFIG_ZYNQ_GEM_EEPROM_ADDR,
+        CONFIG_ZYNQ_GEM_I2C_MAC_OFFSET,
+        enetaddr, ARRAY_SIZE(enetaddr)))
+        printf("I2C EEPROM MAC address read failed\n");
+    else
+        eth_setenv_enetaddr("ethaddr", enetaddr);
+  #endif
+
  switch ((zynq_slcr_get_boot_mode()) & ZYNQ_BM_MASK) {
  case ZYNQ_BM_QSPI:
```

\$ vi common/main.c

common/main.c

```
if (cli_process_fdt(&s))
    cli_secure_boot_cmd(s);

+    setenv("fdt_high", "0x1E000000");
+    setenv("sdboot", "echo Importing environment from SD... && mmcinfo && fatload mmc 0 0x2000000 uEnv.txt &&
env import -t 0x2000000 ${filesize} && boot");

autoboot_command(s);
```

```
$ cp ../zynq-zyboc.dts arch/arm/dts
$ cp ../zynq_zyboc.h include/configs
$ cp ../zynq_zyboc_defconfig configs
```

arch/arm/dts/zynq-zyboc.dts

```
/dts-v1/;
#include "zynq-7000.dtsi"

/ {
    model = "Zynq ZYBOC Development Board";
    compatible = "inipro,zynq-zyboc", "xlnx,zynq-7000";

    aliases {
        ethernet0 = &gem0;
        serial0 = &uart1;
    };

    memory {
        device_type = "memory";
        reg = <0x0 0x20000000>;
    };

    chosen {
        bootargs = "earlyprintk";
        linux,stdout-path = &uart1;
        stdout-path = &uart1;
    };
};
```

```
&clkc {
    ps-clk-frequency = <50000000>;
};

&gem0 {
    status = "okay";
    phy-mode = "rgmii-id";
    phy-handle = <&ethernet_phy>;

    ethernet_phy: ethernet-phy@0 {
        reg = <0>;
    };
};

&sdhci0 {
    status = "okay";
};

&uart1 {
    status = "okay";
};
```

include/configs/zynq_zyboc.h

```
#ifndef __CONFIG_ZYNQ_ZYBOC_H
#define __CONFIG_ZYNQ_ZYBOC_H

#define CONFIG_SYS_SDRAM_SIZE (512 * 1024 * 1024)

#define CONFIG_ZYNQ_SERIAL_UART1
#define CONFIG_ZYNQ_GEM0
#define CONFIG_ZYNQ_GEM_PHY_ADDR0 0

#define CONFIG_SYS_NO_FLASH

#define CONFIG_ZYNQ_SDHCI0
#define CONFIG_ZYNQ_I2C0
#define CONFIG_SYS_I2C_EEPROM_ADDR_LEN 1
#define CONFIG_CMD_EEPROM
#define CONFIG_ZYNQ_GEM_EEPROM_ADDR 0x50
#define CONFIG_ZYNQ_GEM_I2C_MAC_OFFSET 0xFA
#define CONFIG_ZYNQ_BOOT_FREEBSD

/* Define ZYBO PS Clock Frequency to 50MHz */
#define CONFIG_ZYNQ_PS_CLK_FREQ 50000000UL

#include <configs/zynq-common.h>

#endif /* __CONFIG_ZYNQ_ZYBOC_H */
```



include/configs/zynq_zyboc.h

```
CONFIG_ARM=y
CONFIG_ARCH_ZYNQ=y
CONFIG_TARGET_ZYNQ_ZYBOC=y
CONFIG_DEFAULT_DEVICE_TREE="zynq-zyboc"
# CONFIG_SYS_MALLOC_F is not set
CONFIG_SPL=y
CONFIG_FIT=y
CONFIG_FIT_VERBOSE=y
CONFIG_FIT_SIGNATURE=y
# CONFIG_CMD_IMLS is not set
# CONFIG_CMD_FLASH is not set
# CONFIG_CMD_SETEXPR is not set
CONFIG_OF_EMBED=y
```

\$ vi arch/arm/dts/Makefile

```
dtb-$(CONFIG_ARCH_ZYNQ) += zynq-zc702.dtb \
zynq-zc706.dtb \
zynq-zed.dtb \
zynq-zybo.dtb \
zynq-microzed.dtb \
zynq-cc108.dtb \
zynq-afx-nand.dtb \
zynq-afx-nor.dtb \
zynq-afx-qspi.dtb \
zynq-cse-nand.dtb \
zynq-cse-nor.dtb \
zynq-cse-qspi.dtb \
zynq-picozed.dtb \
zynq-zc770-xm010.dtb \
zynq-zc770-xm011.dtb \
zynq-zc770-xm012.dtb \
- zynq-zc770-xm013.dtb
+ zynq-zc770-xm013.dtb \
+ zynq-zyboc.dtb
```




```
$ vi arch/arm/mach-zynq/Kconfig
```

```
config TARGET_ZYNQ_ZYBO
    bool "Zynq Zybo Board"
    select ZYNQ_CUSTOM_INIT

config TARGET_ZYNQ_AFX
    bool "Zynq AFX Board"
    select ZYNQ_CUSTOM_INIT

config TARGET_ZYNQ_CSE
    bool "Zynq CSE Board"
    select ZYNQ_CUSTOM_INIT

config TARGET_ZYNQ_CC108
    bool "Zynq CC108 Board"
    select ZYNQ_CUSTOM_INIT

+config TARGET_ZYNQ_ZYBOC
+    bool "Zynq ZyboC Board"
+    select ZYNQ_CUSTOM_INIT
+
+.....
+
config SYS_CONFIG_NAME
    default "zynq_zed" if TARGET_ZYNQ_ZED
    default "zynq_microzed" if TARGET_ZYNQ_MICROZED
    default "zynq_picozed" if TARGET_ZYNQ_PICOZED
    default "zynq_zc70x" if TARGET_ZYNQ_ZC702 || TARGET_ZYNQ_ZC706 \
        || TARGET_ZYNQ_ZC70X
    default "zynq_zc770" if TARGET_ZYNQ_ZC770
    default "zynq_zybo" if TARGET_ZYNQ_ZYBO
    default "zynq_cse" if TARGET_ZYNQ_CSE
    default "zynq_afx" if TARGET_ZYNQ_AFX
    default "zynq_cc108" if TARGET_ZYNQ_CC108
+    default "zynq_zyboc" if TARGET_ZYNQ_ZYBOC
+

endif
```



```
$ make arch=ARM zynq_zybos_defconfig  
$ make arch=ARM CROSS_COMPILE=arm-linux-gnueabihf- CFLAGS="-O2  
-mtune=cortex-a9 -mcpu=neon -mfloat-abi=hard" all  
$ cp u-boot ~/work/embedded_linux/vivado/u-boot.elf
```



- **Kernel driver** for platform devices

= Kernel source code + Device Tree

Hierarchy of Devices

Provide register address, irq number, so on as property of device.

- **Platform device**

Instead of being dynamically detected, must be statically described in either:

Kernel source code or Device Tree

The devices on I2C buses or SPI buses, or the devices directly part of the system-on-chip.



```
$ cd ~/work/embedded_linux
$ cp vivado/embedded_linux/embedded_linux.tree/system.dts .
$ vi system.dts
```

system.dts

```
&clkc {
    fclk-enable = <0x0>;
    ps-clk-frequency = <50000000>;
};

+&gem0 {
+    phy-handle = <&phy0>;
+    ps7_ethernet_0_mdio: mdio {
+        #address-cells = <0x1>;
+        #size-cells = <0x0>;
+        phy0: phy@0 {
+            compatible = "realtek,RTL8211E";
+            device_type = "ethernet-phy";
+            reg = <0>;
+        };
+    };
+};
```

```
+&i2c0 {
+    eeprom@50 {
+        /* Microchip 24AA02E48 */
+        compatible = "microchip,24c02";
+        reg = <0x50>;
+        pagesize = <8>;
+    };
+};
+/{
+    usb_phy0: phy0 {
+        compatible = "ulpi-phy";
+        #phy-cells = <0>;
+        reg = <0xe0002000 0x1000>;
+        view-port = <0x0170>;
+        drv-vbus;
+    };
+};
+&usb0 {
+    usb-phy = <&usb_phy0>;
+};
```

```
$ dtc -O dtb -I dts -i vivado/embedded_linux/embedded_linux.tree/ -o
devicetree.dtb system.dts
```

```
$ cd ~/work/embedded_linux
$ wget https://github.com/Xilinx/linux-xlnx/archive/xilinx-v2015.4.01.tar.gz -O
dl/linux-xlnx-xilinx-v2015.4.01.tar.gz
$ cd kernel
$ tar xvzf ../dl/linux-xlnx-xilinx-v2015.4.01.tar.gz
$ cd linux-xlnx-xilinx-v2015.4.01
$ cp -r ../drivers/rtl8192cu drivers/net/wireless/
$ vi drivers/net/wireless/Kconfig
```

drivers/net/wireless/Kconfig

```
source "drivers/net/wireless/mwifiex/Kconfig"
source "drivers/net/wireless/cw1200/Kconfig"
source "drivers/net/wireless/rsi/Kconfig"
+source "drivers/net/wireless/rtl8192cu/Kconfig"

endif # WLAN
```

```
$ vi drivers/net/wireless/Makefile
```

drivers/net/wireless/Makefile

```
obj-$(CONFIG_CW1200) += cw1200/
obj-$(CONFIG_RSI_91X) += rsi/
+obj-$(CONFIG_RTL8192CU) += rtl8192cu/
```

```
$ make ARCH=arm xilinx_zynq_defconfig
```

```
$ make ARCH=arm menuconfig
```




```
hokim@ubuntu: ~/work/embedded_linux/kernel/linux-xlnx-xilinx-v2015.4.01
.config - Linux/arm 4.0.0 Kernel Configuration
> Networking support > Wireless

Wireless
Arrow keys navigate the menu. <Enter> selects submenus ---> (or empty
submenus ----). Highlighted letters are hotkeys. Pressing <Y>
includes, <N> excludes, <M> modularizes features. Press <Esc><Esc> to
exit, <?> for Help, </> for Search. Legend: [*] built-in [ ]

--- Wireless
[*] cfg80211 - wireless configuration API
[ ] nl80211 testmode command (NEW)
[ ] enable developer warnings (NEW)
[ ] cfg80211 regulatory debugging (NEW)
[ ] cfg80211 certification onus (NEW)
[*] enable powersave by default (NEW)
[ ] use statically compiled regulatory rules database (NEW)
[ ] cfg80211 wireless extensions compatibility (NEW)
[*] Generic IEEE 802.11 Networking Stack (mac80211)
+ (+)

<Select> < Exit > < Help > < Save > < Load >

hokim@ubuntu: ~/work/embedded_linux/kernel/linux-xlnx-xilinx-v2015.4.01
.config - Linux/arm 4.0.0 Kernel Configuration
> Device Drivers > Device Tree and Open Firmware support

Device Tree and Open Firmware support
Arrow keys navigate the menu. <Enter> selects submenus ---> (or empty
submenus ----). Highlighted letters are hotkeys. Pressing <Y>
includes, <N> excludes, <M> modularizes features. Press <Esc><Esc> to
exit, <?> for Help, </> for Search. Legend: [*] built-in [ ]

[ ] Device Tree runtime unit tests
[*] Device Tree overlays

<Select> < Exit > < Help > < Save > < Load >
```



```
hokim@ubuntu: ~/work/embedded_linux/kernel/linux-xlnx-xilinx-v2015.4.01
.config - Linux/arm 4.0.0 Kernel Configuration
[...] rivers > Network device support > PHY Device support and infrastructure
PHY Device support and infrastructure
Arrow keys navigate the menu. <Enter> selects submenus ---> (or empty
submenus ----). Highlighted letters are hotkeys. Pressing <Y>
includes, <N> excludes, <M> modularizes features. Press <Esc><Esc> to
exit, <?> for Help, </> for Search. Legend: [*] built-in [ ]

^(-)
< > Drivers for the Intel LXT PHYs
< > Drivers for the Cicada PHYs
<*> Drivers for the Vitesse PHYs
< > Drivers for SMSC PHYs
< > Drivers for Broadcom PHYs
< > Drivers for Broadcom 7xxx SOCs internal PHYs
< > Driver for Broadcom BCM8706 and BCM8727 PHYs
< > Drivers for ICPlus PHYs
<*> Drivers for Realtek PHYs
< > Drivers for National Semiconductor PHYs
+ (+)

<Select> < Exit > < Help > < Save > < Load >
```

```
hokim@ubuntu: ~/work/embedded_linux/kernel/linux-xlnx-xilinx-v2015.4.01
.config - Linux/arm 4.0.0 Kernel Configuration
> Device Drivers > Network device support > Wireless LAN
Wireless LAN
Arrow keys navigate the menu. <Enter> selects submenus ---> (or empty
submenus ----). Highlighted letters are hotkeys. Pressing <Y>
includes, <N> excludes, <M> modularizes features. Press <Esc><Esc> to
exit, <?> for Help, </> for Search. Legend: [*] built-in [ ]

^(-)
< > Hermes chipset 802.11b support (Orinoco/Prism2/Symbol) (NEW)
< > Softmac Prism54 support (NEW)
< > Ralink driver support (NEW) ----
< > Realtek rtlwifi family of devices ----
[ ] TI Wireless LAN support ----
< > ZyDAS ZD1211/ZD1211B USB-wireless support (NEW)
< > Marvell WiFi-Ex Driver (NEW)
< > CW1200 WLAN support (NEW)
< > Redpine Signals Inc 91x WLAN driver support (NEW)
<*> Realtek 8192C USB WiFi

<Select> < Exit > < Help > < Save > < Load >
```




```
hokim@ubuntu: ~/work/embedded_linux/kernel/linux-xlnx-xilinx-v2015.4.01
.config - Linux/arm 4.0.0 Kernel Configuration
> Device Drivers > SPI support

SPI support
Arrow keys navigate the menu. <Enter> selects submenus ---> (or empty
submenus ----). Highlighted letters are hotkeys. Pressing <Y>
includes, <N> excludes, <M> modularizes features. Press <Esc><Esc> to
exit, <?> for Help, </> for Search. Legend: [*] built-in [ ]

^(-)
< > NXP SC18IS602/602B/603 I2C to SPI bridge
< > Analog Devices AD-FMCOMMS1-EBZ SPI-I2C-bridge driver
<*> Xilinx SPI controller common module
<*> Xilinx Zynq QSPI controller
[ ] Xilinx Zynq QSPI Dual stacked configuration
< > Xilinx ZynqMP QSPI controller
< > DesignWare SPI controller core support
*** SPI Protocol Masters ***
<*> User mode SPI device driver support
< > Infineon TLE62X0 (for power switching)

<Select> < Exit > < Help > < Save > < Load >
```

```
hokim@ubuntu: ~/work/embedded_linux/kernel/linux-xlnx-xilinx-v2015.4.01
.config - Linux/arm 4.0.0 Kernel Configuration
> Device Drivers > GPIO Support

GPIO Support
Arrow keys navigate the menu. <Enter> selects submenus ---> (or empty
submenus ----). Highlighted letters are hotkeys. Pressing <Y>
includes, <N> excludes, <M> modularizes features. Press <Esc><Esc> to
exit, <?> for Help, </> for Search. Legend: [*] built-in [ ]

^(-)
< > GPIO driver for 74xx-ICs with MMIO access
-* Generic memory-mapped GPIO controller support (MMIO platfor
< > Synopsys DesignWare APB GPIO driver
< > Emma Mobile GPIO
[ ] LSI ZEVIO SoC memory mapped GPIOs
[ ] PrimeCell PL061 GPIO support
< > SMSC SCH311x SuperI/O GPIO
< > GPIO based on SYSCON
<*> Xilinx GPIO support
<*> Xilinx Zynq GPIO support
^(+)
```

```
<Select> < Exit > < Help > < Save > < Load >
```



```
$ make ARCH=arm CROSS_COMPILE=arm-linux-gnueabihf- CFLAGS="-O2  
-mtune=cortex-a9 -mfpu=neon -mfloat-abi=hard" -j $(nproc)  
UIMAGE_LOADADDR=0x8000 ulmage  
$ cp arch/arm/boot/ulmage ../..
```



```
$ cd ~/work/embedded_linux  
$ sudo sh ./image.sh
```

image.sh

```
mkdir -p dl  
  
UBUNTU_URL=http://cdimage.ubuntu.com/ubuntu-base/releases/16.04/release  
UBUNTU=ubuntu-base-16.04-core-armhf.tar.gz  
if [ ! -f dl/$UBUNTU ]; then  
    wget $UBUNTU_URL/$UBUNTU -O dl/$UBUNTU  
fi  
  
ARCH=armhf  
SIZE=3500  
mkdir -p img  
IMAGE=img/ubuntu-core_${ARCH}_16.04.img  
dd if=/dev/zero of=$IMAGE bs=1M count=$SIZE  
DEVICE=$(losetup -f)  
losetup $DEVICE $IMAGE  
parted -s $DEVICE mklabel msdos  
parted -s $DEVICE mkpart primary fat16 4MB 128MB  
parted -s $DEVICE mkpart primary ext4 128MB 100%  
BOOT_DEV=/dev/$(lsblk -lno NAME $DEVICE | sed '2!d')  
ROOT_DEV=/dev/$(lsblk -lno NAME $DEVICE | sed '3!d')  
mkfs.vfat -v $BOOT_DEV  
mkfs.ext4 -F -j $ROOT_DEV  
ROOT_DIR=root  
mkdir -p $ROOT_DIR  
mount $ROOT_DEV $ROOT_DIR  
cd $ROOT_DIR  
tar xvf ../dl/$UBUNTU  
rm -fr boot  
cd ..
```



image.sh

```
cat > $ROOT_DIR/etc/fstab << EOF_CAT
# /etc/fstab: static file system information.
# <file system> <mount point> <type> <options> <dump> <pass>
/dev/mmcb1k0p1 /boot vfat errors=remount-ro 0 0
/dev/mmcb1k0p2 / ext4 errors=remount-ro 0 1
EOF_CAT

cp /etc/resolv.conf $ROOT_DIR/etc/
cp /usr/bin/qemu-arm-static $ROOT_DIR/usr/bin/
chroot $ROOT_DIR << EOF_CHROOT
sed -i 's/^# deb http://ports.ubuntu.com/ubuntu-ports/ xenial universe.*/deb http://ports.ubuntu.com/ubuntu-ports/
xenial universe/' /etc/apt/sources.list
sed -i 's/^# deb http://ports.ubuntu.com/ubuntu-ports/ xenial-updates universe.*/deb http://ports.ubuntu.com/ubuntu-
ports/ xenial-updates universe/' /etc/apt/sources.list
apt-get update
apt-get -y upgrade
DEBIAN_FRONTEND=noninteractive apt-get -y install vim sudo openssh-server udev usbutils u-boot-tools device-tree-
compiler kmod net-tools wpasupplicant parted rkill lshw wireless-tools gcc g++ cmake git i2c-tools iputils-ping
echo "Asia/Seoul" > /etc/timezone
ln -fs /usr/share/zoneinfo/Asia/Seoul /etc/localtime
locale-gen "en_US.UTF-8"
DEBIAN_FRONTEND=noninteractive dpkg-reconfigure locales
EOF_CHROOT
rm $ROOT_DIR/etc/resolv.conf
rm $ROOT_DIR/usr/bin/qemu-arm-static

mkdir -pv $ROOT_DIR/etc/systemd/system/serial-getty\@ttyPS0.service.d
cat > $ROOT_DIR/etc/systemd/system/serial-getty\@ttyPS0.service.d/autologin.conf << EOF_CAT
[Service]
ExecStart=
ExecStart=-/sbin/agetty --autologin root -s %I 115200,38400,9600 linux
EOF_CAT
umount -l $ROOT_DIR
rmdir $ROOT_DIR
losetup -d $DEVICE
```

using WinSCP

Ubuntu	Windows
~/work/embedded_linux/ devicetree.dtb, ulmage	C:\Users\Whokim\work\embedded_linux
~/work/embedded_linux/vivado/ u-boot.elf	C:\Users\Whokim\work\embedded_linux\vivado
~/work/embedded_linux/img/ ubuntu-core_armhf_16.04.img	C:\Users\Whokim\work



bootbin.tcl

```
# tclsh bootbin.tcl

set project_name embedded_linux

set fileId [open $project_name/boot.bif "w"]
puts $fileId "img: {[bootloader\] $project_name/$project_name.fsbl/executable.elf
$project_name/$project_name.runs/impl_1/system_wrapper.bit u-boot.elf}"
close $fileId

file delete -force boot.bin

exec bootgen -image $project_name/boot.bif -w -o i boot.bin >&@stdout
```

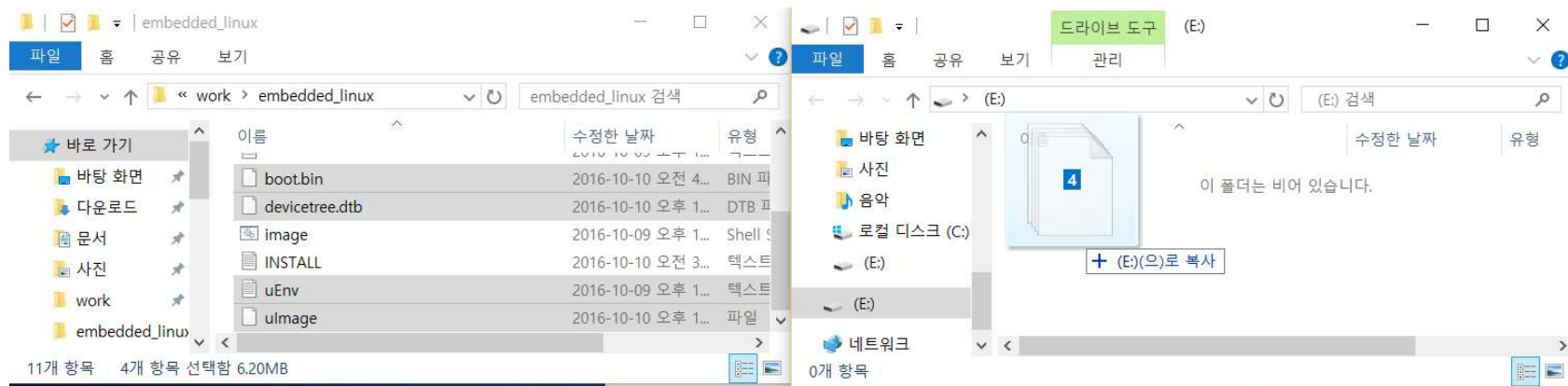
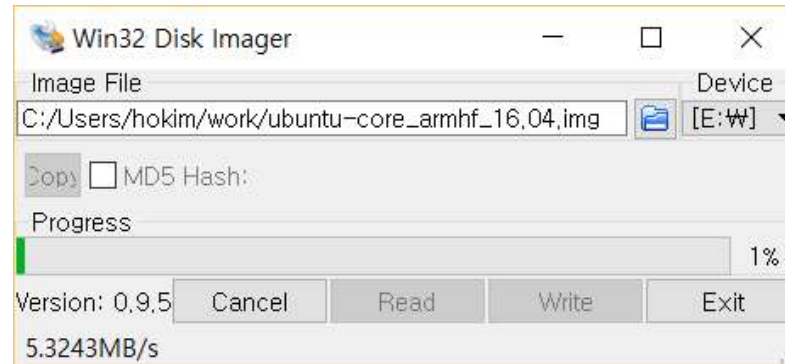
In cmd window for Vivado

```
C:\ cd c:\Users\hokim\work\embedded_linux\vivado
C:\ tclsh bootbin.tcl
C:\ copy boot.bin ..
```

output : boot.bin



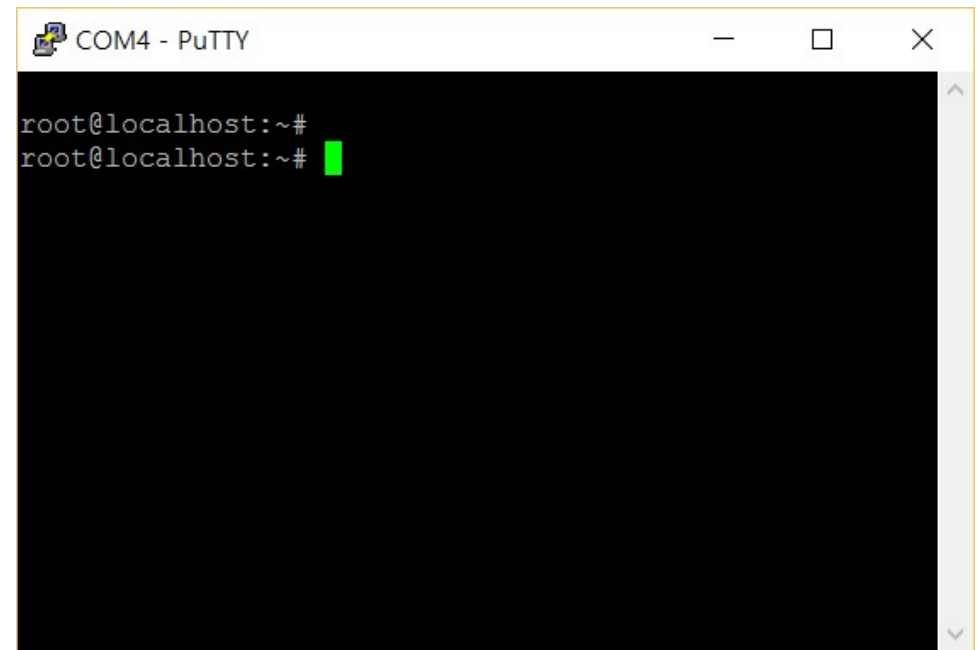
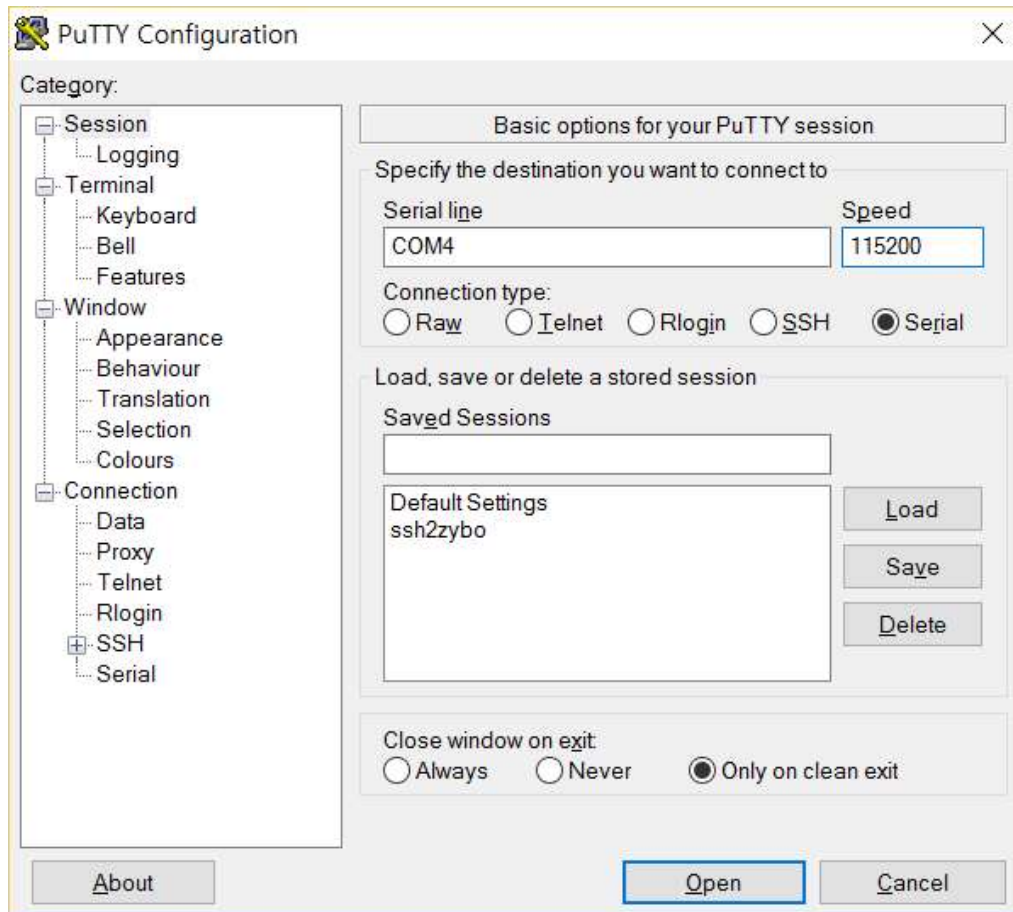
<https://sourceforge.net/projects/win32diskimager/>



Boot zybo with SD card



Log in through UART console using putty




```
# groupadd -g 1000 hokim
# groupadd -g 1001 admin
# useradd -u 1000 -g 1000 -G adm,dialout,cdrom,audio,dip,video,plugdev,admin
-d /home/hokim -m -s /bin/bash hokim
# passwd hokim
# vi /etc/network/interfaces.d/eth0
```

/etc/network/interfaces.d/eth0

```
allow-hotplug eth0
iface eth0 inet static
address 192.168.10.10
netmask 255.255.255.0
```

```
# halt
```

Turn off/on zybo



Log in through ethernet using putty

인터넷 프로토콜 버전 4(TCP/IPv4) 속성

일반

네트워크가 IP 자동 설정 기능을 지원하면 IP 설정이 자동으로 할당되도록 할 수 있습니다. 지원하지 않으면, 네트워크 관리자에게 적절한 IP 설정값을 문의해야 합니다.

☐ 자동으로 IP 주소 받기(O)

☒ 다음 IP 주소 사용(S):

IP 주소(I): 192 . 168 . 10 . 100

서브넷 마스크(U): 255 . 255 . 255 . 0

기본 게이트웨이(D): . . .

☐ 자동으로 DNS 서버 주소 받기(B)

☒ 다음 DNS 서버 주소 사용(E):

기본 설정 DNS 서버(P): . . .

보조 DNS 서버(A): . . .

☐ 끝날 때 설정 유효성 검사(L)

고급(V)...

확인 취소

PuTTY Configuration

Category:

- Session
- Logging
- Terminal
 - Keyboard
 - Bell
 - Features
- Window
 - Appearance
 - Behaviour
 - Translation
 - Selection
 - Colours
- Connection
 - Data
 - Proxy
 - Telnet
 - Rlogin
 - SSH
 - Serial

Basic options for your PuTTY session

Specify the destination you want to connect to

Host Name (or IP address) 192.168.10.10 Port 22

Connection type:
☐ Raw ☐ Telnet ☐ Rlogin ☒ SSH ☐ Serial

Load, save or delete a stored session

Saved Sessions

Default Settings

Load Save Delete

Close window on exit:
☐ Always ☐ Never ☒ Only on clean exit

About Open Cancel

```
$ sudo vi /etc/hostname
```

/etc/hostname

```
-localhost.localdomain  
+zybo
```

```
$ sudo vi /etc/hosts
```

/etc/hosts

```
127.0.0.1    localhost  
127.0.1.1    zybo  
  
# The following lines are desirable for IPv6 capable hosts  
::1         ip6-localhost ip6-loopback  
fe00::0     ip6-localnet  
ff00::0     ip6-mcastprefix  
ff02::1     ip6-allnodes  
ff02::2     ip6-allrouters
```

```
$ ls /sys/class/net
```

output:

```
enx74da38422193 eth0 lo
```



```
$ sudo vi /etc/network/interfaces.d/enx74da38422193
```

/etc/network/interfaces.d/enx74da38422193

```
allow-hotplug enx74da38422193
iface enx74da38422193 inet dhcp
    pre-up wpa_supplicant -B -D wext -i enx74da38422193 -c /etc/wpa_supplicant.conf
    post-down killall -q wpa_supplicant
    udhcpc_opts -t7 -T3
```

```
$ sudo vi /etc/wpa_supplicant.conf
```

/etc/wpa_supplicant.conf

```
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1

network={
    ssid="INIPRO"
    key_mgmt=WPA-PSK
    psk="20471047"
}
```

```
$ sudo halt
```

Turn off/on zybo



```
$ sudo vi /etc/network/interfaces.d/enx74da38422193
```

/etc/network/interfaces.d/enx74da38422193

```
allow-hotplug enx74da38422193
iface enx74da38422193 inet dhcp
    pre-up wpa_supplicant -B -D wext -i enx74da38422193 -c /etc/wpa_supplicant.conf
    post-down killall -q wpa_supplicant
    udhcpc_opts -t7 -T3
```

```
$ sudo vi /etc/wpa_supplicant.conf
```

/etc/wpa_supplicant.conf

```
ctrl_interface=DIR=/var/run/wpa_supplicant GROUP=netdev
update_config=1

network={
    ssid="INIPRO"
    key_mgmt=WPA-PSK
    psk="20471047"
}
```

```
$ sudo -s
# echo -e "d\n2\nw" | fdisk /dev/mmcblk0
# parted -s /dev/mmcblk0 mkpart primary ext4 128M 100%
# halt
```


Turn off / on zybo

Log in through ethernet using putty

```
$ sudo resize2fs /dev/mmcblk0p2  
$ df -h
```

output:

Filesystem	Size	Used	Avail	Use%	Mounted on
/dev/root	7.0G	632M	6.0G	10%	/
devtmpfs	242M	0	242M	0%	/dev
tmpfs	250M	0	250M	0%	/dev/shm
tmpfs	250M	6.5M	244M	3%	/run
tmpfs	5.0M	0	5.0M	0%	/run/lock
tmpfs	250M	0	250M	0%	/sys/fs/cgroup
/dev/mmcblk0p1	118M	6.3M	112M	6%	/boot



```
$ ifconfig
```

output:

```
enx74da38422193 Link encap:Ethernet HWaddr 74:da:38:42:21:93
    inet addr:192.168.0.148 Bcast:192.168.0.255 Mask:255.255.255.0
    UP BROADCAST RUNNING MULTICAST MTU:1500 Metric:1
    RX packets:418 errors:0 dropped:3 overruns:0 frame:0
    TX packets:12 errors:0 dropped:0 overruns:0 carrier:0
    collisions:0 txqueuelen:1000
    RX bytes:77995 (77.9 KB) TX bytes:1772 (1.7 KB)

eth0    Link encap:Ethernet HWaddr d8:80:39:5c:48:82
    inet addr:192.168.10.10 Bcast:192.168.10.255 Mask:255.255.255.0
    UP BROADCAST RUNNING MULTICAST MTU:1500 Metric:1
    RX packets:437 errors:0 dropped:1 overruns:0 frame:0
    TX packets:448 errors:0 dropped:0 overruns:0 carrier:0
    collisions:0 txqueuelen:1000
    RX bytes:33219 (33.2 KB) TX bytes:57605 (57.6 KB)
    Interrupt:145 Base address:0xb000

lo      Link encap:Local Loopback
    inet addr:127.0.0.1 Mask:255.0.0.0
    UP LOOPBACK RUNNING MTU:65536 Metric:1
    RX packets:80 errors:0 dropped:0 overruns:0 frame:0
    TX packets:80 errors:0 dropped:0 overruns:0 carrier:0
    collisions:0 txqueuelen:0
    RX bytes:5920 (5.9 KB) TX bytes:5920 (5.9 KB)
```

