Android System Development
Day - 3

By Team Emertxe

EMERTXE

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Android HAL Overview

Why Android HAL?

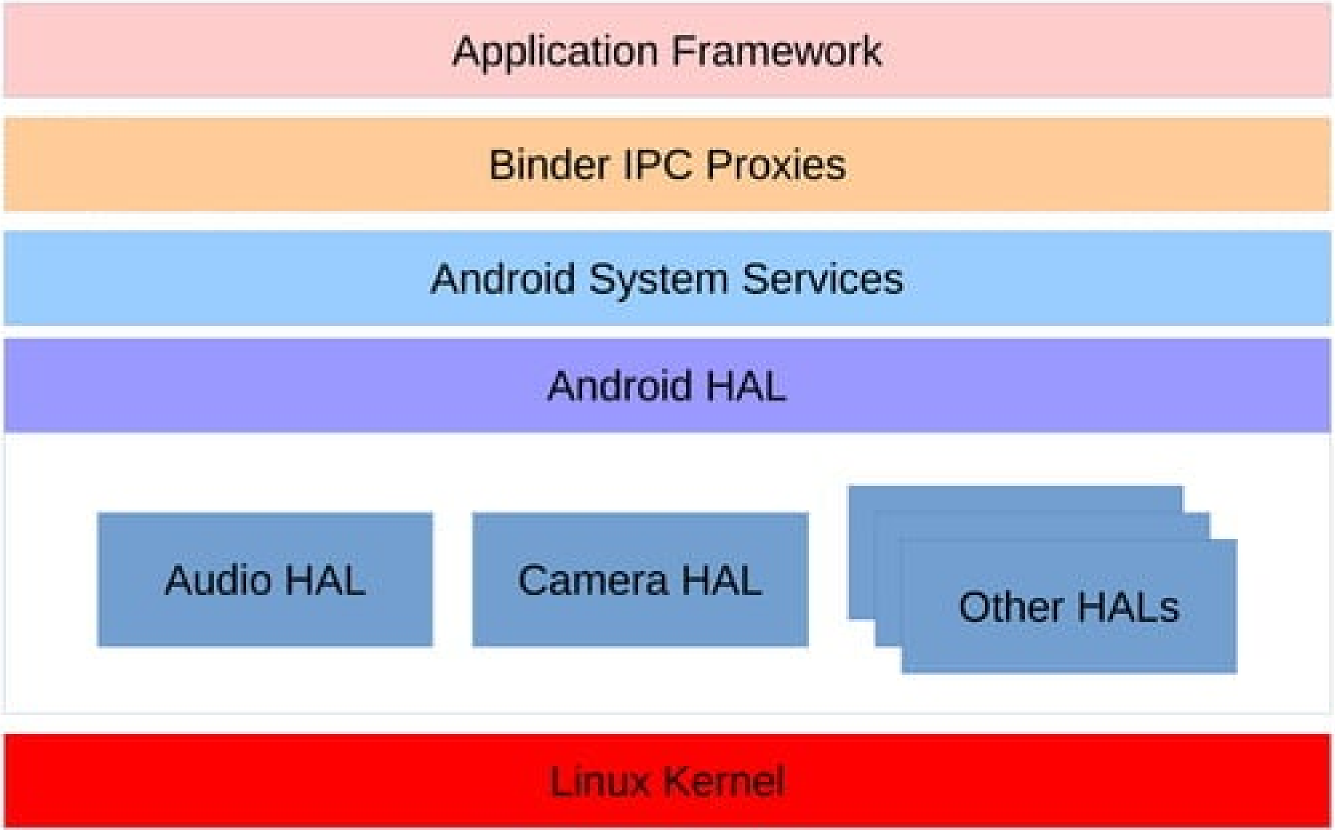
- Linux is designed to handle only systems calls from application
- Android frameworks communicates with the underlying hardware through Java APIs not by system calls
- Android HAL bridges the gap between Android app framework and Linux device driver interface
- The HAL allows you to implement functionality without affecting or modifying higher level system

What is Android HAL?

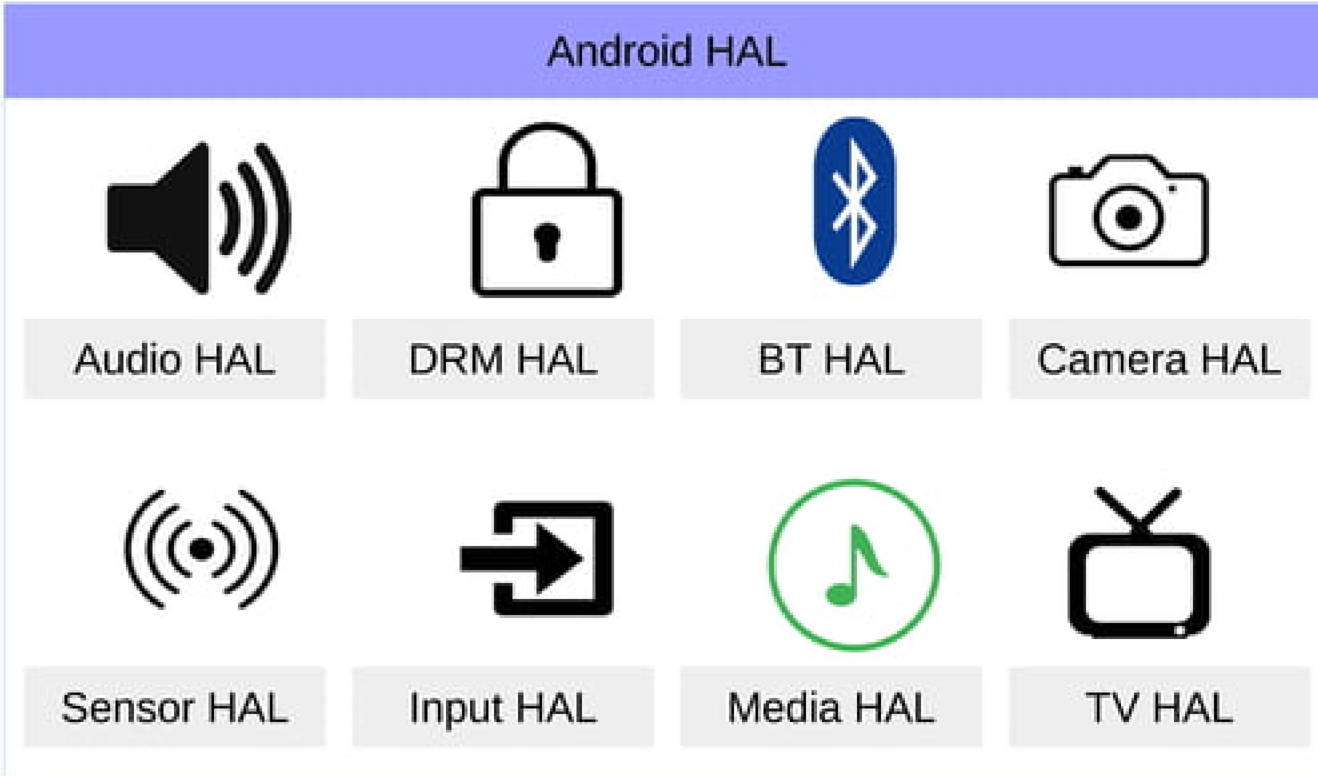
"The hardware abstraction layer (HAL) defines a standard interface for hardware vendors to implement and allows Android to be agnostic about lower-level driver implementations"

- Provides API's through which Android service can place a request to device
- Uses functions provided by Linux system to service the request from android framework
- A C/C++ layer with purely vendor specific implementation
- Packaged into modules (.so) file & loaded by Android system at appropriate time

Android System
(Architecture)



Android HAL
(Architecture)

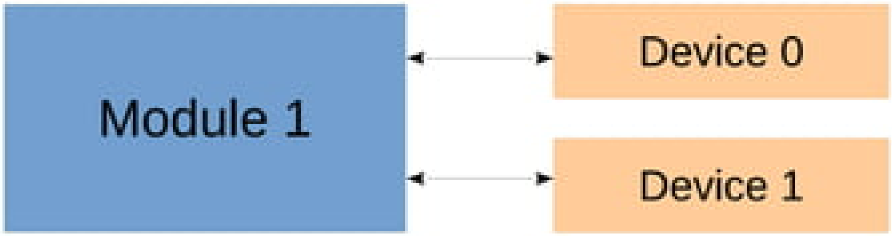


Android HAL
(Architecture)

- Each hardware-specific HAL interface has properties that are defined in hardware/libhardware/include/hardware/hardware.h
- It guarantees that HALs have a predictable structure
- Above interface allows Android system to load correct versions of your HAL modules consistently

Android HAL
(Architecture)

- HAL interface consists of two general components
  - Module - Android HAL - automatically loaded by the dynamic linker (sensor.rpi3.so)
  - Device – Device Specific HAL (provides complete abstraction and control over device vendor) – appropriately loaded at run time



Android HAL
(Module)

- A module, stored as a shared library (.so file), represents packaged HAL implementation
- Contains metadata such as version, name, and author of the module, which helps Android find and load it correctly
- The "hardware.h" header file defines struct hw_module_t
- This strtucture represents a module & contains information such as module version, author and name
- API are in <aosp>/hardware/libhardware/include/hardware

Android HAL
(Module…)

- In addition, hw_module_t struct contains a pointer to another struct, hw_module_methods_t, that contains a pointer to an "open" function for the module
- "open" function is used to initiate communication with the hardware
- Each "hardware-specific HAL" usually extends generic hw_module_t struct with additional information for that specific piece of hardware

Android HAL
(Module hw_module_t)

#	Member	Type	Description
1	tag	Integer	HARDWARE_MODULE_TAG
2	module_api_version	Interger	Module interface version (Minor + Major)
3	hal_api_version	Integer	Meant to version module, module methods and device
4	id	String	Ex - “DHT11”
5	name	String	Ex - “Temperature Sensor”
6	author	String	Ex - “Emertxe”
7	methods	Pointer	Open method
8	dso	Pointer	Pointer to DSOs
9	Reserved	Bytes	Reserved 128 bytes for future use

Android HAL
(Module…)

- For example in the camera HAL, the camera_module_t struct contains a hw_module_t struct along with other camera-specific function pointers

```
typedef struct camera_module {
    hw_module_t common;
    int (*get_number_of_cameras)(void);
    int (*get_camera_info)(int camera_id, struct camera_info *info);
} camera_module_t;
```

Android HAL
(Naming a module)

- Use HAL_MODULE_INFO_SYM name while creating module in your HAL
- Example : Audio module

```
struct audio_module HAL_MODULE_INFO_SYM = {
    .common = {
        .tag = HARDWARE_MODULE_TAG,
        .module_api_version = AUDIO_MODULE_API_VERSION_0_1,
        .hal_api_version = HARDWARE_HAL_API_VERSION,
        .id = AUDIO_HARDWARE_MODULE_ID,
        .name = "NVIDIA Tegra Audio HAL",
        .author = "The Android Open Source Project",
        .methods = &hal_module_methods,
    },
};
```

Android HAL
(Device)

- A device abstracts the actual hardware of your product
- Example: an audio module can contain a primary audio device (ear-jack), a USB audio device, or a Bluetooth A2DP audio device
- A device is represented by the hw_device_t structure
- APIs are in <aosp>/hardware/libhardware_legacy/include/hardware_legacy

HAL
(Module hw_device_t)

#	Member	Type	Description
1	tag	Integer	HARDWARE_DEVICE_TAG
2	version	Interger	Device API version
3	module	Pointer	Reference to module hw_module_t
4	Padding	Interger	Reserved 48 bytes for future use
5	close	Pointer	To close function

Android HAL
(Device…)

- Like a module, each type of device defines a more-detailed version of the generic hw_device_t that contains function pointers for specific features of the hardware
- Example : the audio_hw_device_t struct type contains function pointers to audio device operations

```
struct audio_hw_device {
    struct hw_device_t common;
...
    uint32_t (*get_supported_devices)(const struct audio_hw_device *dev);
...
};
typedef struct audio_hw_device audio_hw_device_t;
```

Android HAL
(Structure)

- LDD is a HAL for Linux, therefore, Android HAL looks similar to a Linux device driver
- Most of the Vendor specific implementations can be done in Android HAL (rather than the driver)
- Therefore, the license difference between driver (Open source license GPL) and HAL (Apache License) will give more level of abstraction to vendor
- The driver triggers hardware (say sensor) and deliver the data back to HAL which is passed back to Android application

Android Sensors Overview

Sensors Overview
(What?)

- A device that responds to a physical stimulus (as heat, light, sound, pressure, magnetism, or a particular motion) and transmits a resulting impulse (as for measurement or operating a control)
  – Merriam Webster Dictionary

Sensors Overview
(What?)

- A sensor is a device that detects and responds to some type of input from the physical environment. The specific input could be light, heat, motion, moisture, pressure, or any one of a great number of other environmental phenomena. The output is generally a signal that is converted to human-readable display at the sensor location or transmitted electronically over a network for reading or further processing
- Examples – temperature, motion, light, gravity etc..

Temperature sensor

Light sensor

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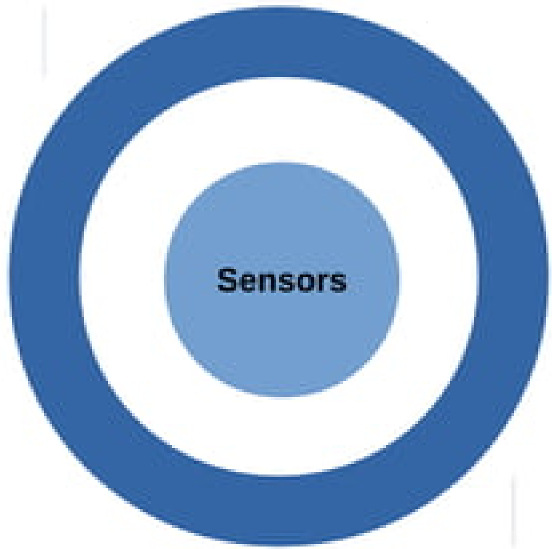
Sensors Overview
(Why?)

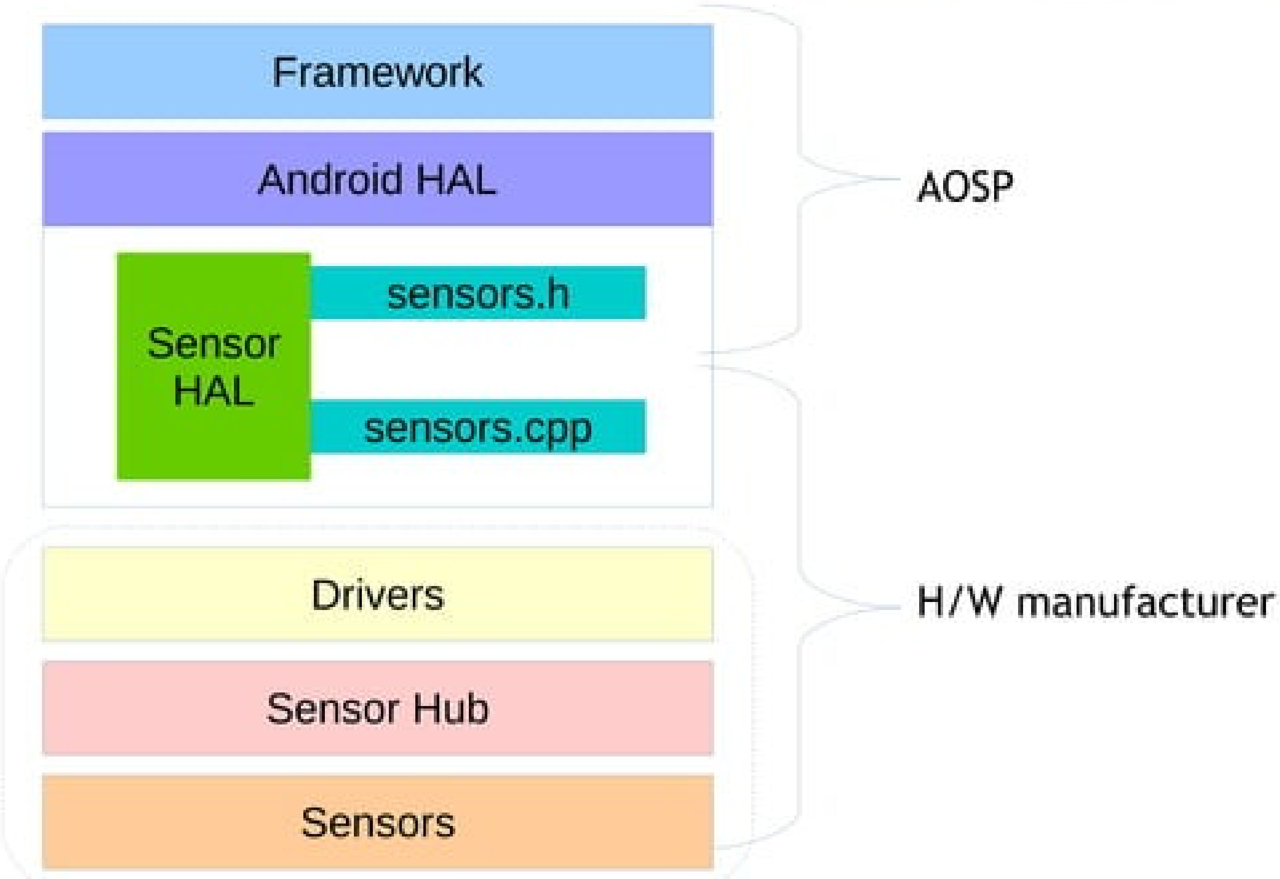
- Sensors are widely used in medical, automation, mining, automobiles, airospace, robotics, smartphones, houses, farming and more…
- The data is collected, processed and results are used in important decision making and actions

- Automation
- Mining
- Automobiles
- Airospace



- Smartphones
- Robotics
- Medical

Sensors overview
(Android Sensor Stack)



Sensors Overview
(Application)

- App access sensors through APIs
- App shall rgister to a sensor
- App specifies its preferred sampling frequency and its latency requirements

- Example :
  - Register with accelerometer
  - Request events at 100Hz
  - Events to be reported with a 1-second latency

- The application will receive events from the accelerometer at a rate of at least 100Hz, and possibly delayed up to 1 second

Sensors Overview
(Framework)

- Framework links several applications to HAL
- HAL itself is single-client
- Requests are multiplexed by framework to enable access to sensors by many apps
- When first app registers to a sensor, the framework sends a request to the HAL to activate the sensor
- Framework sends updated requested parameters to HAL for additional registeration requests from other apps to same sensor
- Frameworks deactivates the sensor on exit of last app to avoid unwanted power consumption

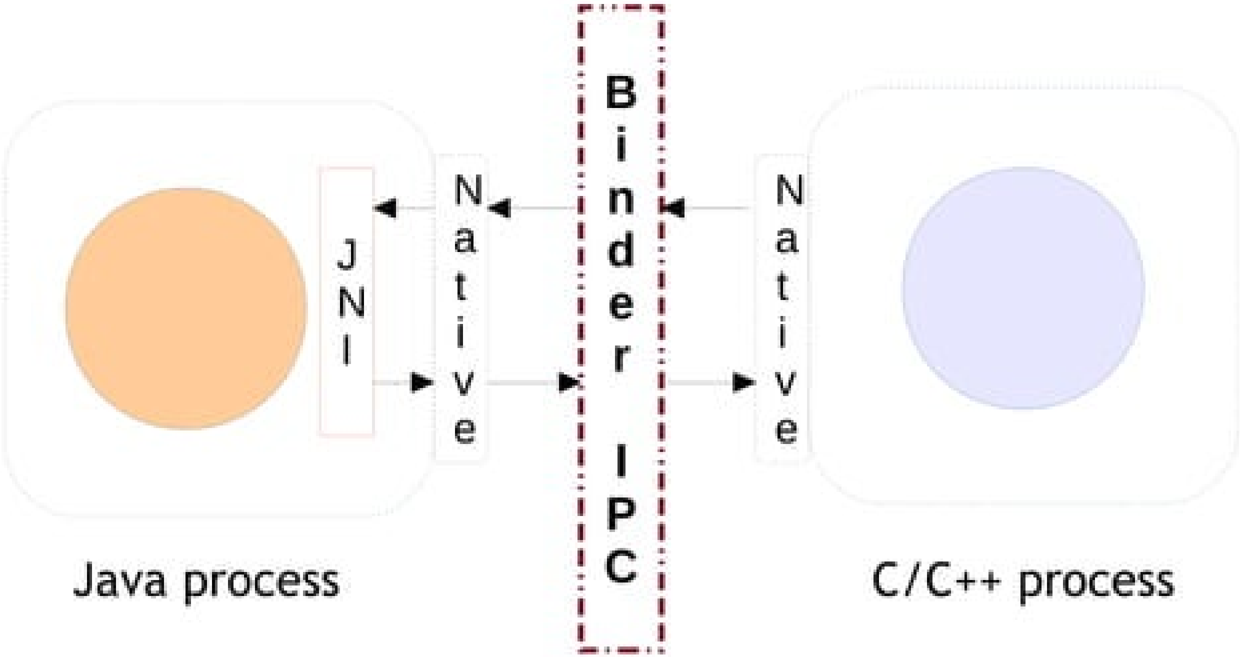
Sensors Overview
(Framework)

- Final Sampling frequency - max of all requested sampling frequencies
- Meaning, some applications will receive events at a frequency higher than the one they requested
- Final maximum reporting latency – min of all requested ones
- If one application requests one sensor with a maximum reporting latency of 0, all applications will receive the events from this sensor in continuous mode even if some requested the sensor with a non-zero maximum reporting latency

Sensors Overview
(Implications of multiplexing)

- No guarantee that events won't arrive at a faster rate
- No mechanism to send data down from the apps to sensors or their drivers
- This ensures one app cannot modify the behavior of sensors and breaking other apps

Sensors Overview
(The communication)



* JNI is located in frameworks/base/core/jni/ directory
* Native framework is located in frameworks/native/

Sensors Overview
(Types)

Motion sensors
- These sensors measure acceleration forces and rotational forces along three axes
- This category includes accelerometers, gravity sensors, gyroscopes, and rotational vector sensors

Environmental sensors
- These sensors measure various environmental parameters, such as ambient air temperature and pressure, illumination, and humidity
- This category includes barometers, photometers, and thermometers

Position sensors
- These sensors measure the physical position of a device
- This category includes orientation sensors and magnetometers

Sensors Overview
(Implementation)

Hardware-based

- Physical components built into a handset or tablet
- Derive their data by directly measuring specific environmental properties such as acceleration, geomagnetic field strength, or angular change

Software-based

- Are not physical devices, although they mimic hardware-based sensors
- Derive their data from one or more of the hardware-based sensors and are sometimes called virtual sensors or synthetic sensors
- The linear acceleration sensor and the gravity sensor are examples of software-based sensors

Sensors Overview
(Types)

Sensor	Type	Description	Common Uses
Accelerometer	Hardware	Measures the acceleration force in m/s^2 that is applied to a device on all three physical axes (x, y, and z), including the force of gravity	Motion detection (shake, tilt, etc.)
Ambient Temprature	Hardware	Measures the ambient room temperature in degrees Celsius (°C). See note below	Monitoring air temperatures
Gravity	Software or Hardware	Measures the force of gravity in m/s^2 that is applied to a device on all three physical axes (x, y, z)	Motion detection (shake, tilt, etc.)
Gyroscope	Hardware	Measures a device's rate of rotation in rad/s around each of the three physical axes (x, y, and z)	Rotation detection (spin, turn, etc.)

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Sensors Overview
(Types)

Sensor	Type	Description	Common Uses
Light	Hardware	Measures the ambient light level (illumination) in lx	Controlling screen brightness
Linear Acceleration	Software or Hardware	Measures the acceleration force in m/s^2 that is applied to a device on all three physical axes (x, y, and z), excluding the force of gravity	Monitoring acceleration along a single axis
Magnetic	Hardware	Measures the ambient geomagnetic field for all three physical axes (x, y, z) in μT	Creating a compass
Orientation	Software	Measures degrees of rotation that a device makes around all three physical axes (x, y, z). As of API level 3 you can obtain the inclination matrix and rotation matrix for a device by using the gravity sensor and the geomagnetic field sensor in conjunction with the getRotationMatrix() method	Determining device position

Sensors Overview
(Types)

Sensor	Type	Description	Common Uses
Pressure	Hardware	Measures the ambient air pressure in hPa or mbar	Monitoring air pressure changes
Proximity	Hardware	Measures the proximity of an object in cm relative to the view screen of a device. This sensor is typically used to determine whether a handset is being held up to a person's ear	Phone position during a call
Humidirt	Hardware	Measures the relative ambient humidity in percent (%)	Monitoring dewpoint, absolute, and relative humidity
Rotation Vector	Software or Hardware	Measures the orientation of a device by providing the three elements of the device's rotation vector	Motion detection and rotation detection

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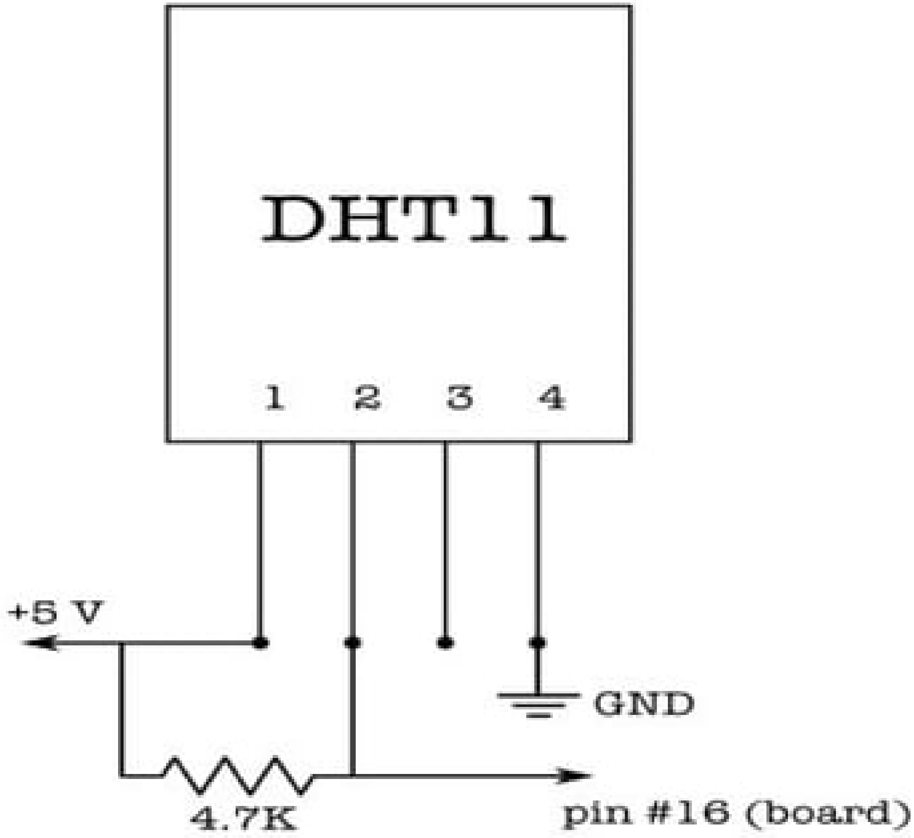
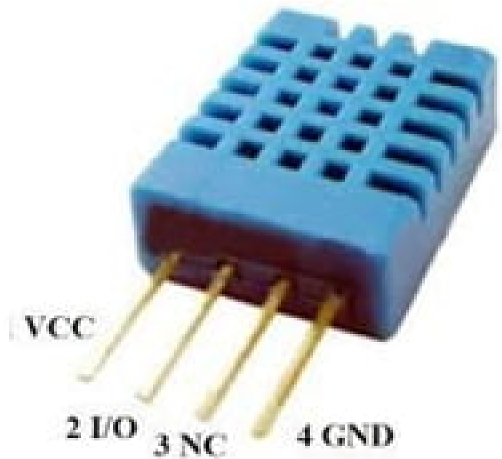
Sensors Overview
(Supported Sensors)

Sensor	Supported	Sensor	Supported
Accelerometer	Yes	Light	Yes
Ambient Temprature	Yes	Linear Acceleration	Yes
Gravity	Yes	Magnetic	Yes
Gyroscope	Yes	Orientation	Yes
Pressure	Yes	Humidirt	Yes
Proximity	Yes	Rotation Vector	Yes

Temprature Sensor
(DHT11)





Android Sensor Framework

Sensor Framework

- The sensor framework is part of the android.hardware package and includes the following classes and interfaces
  - SensorManager
  - Sensor
  - SensorEvent
  - SensorEventListener

Sensor Framework

Android Sensor Framework can be used for -

- Determine which sensors are available on a device
- Determine an individual sensor's capabilities, such as its maximum range, manufacturer, power requirements and resolution
- Acquire raw sensor data and define the minimum rate at which you acquire sensor data
- Register and unregister sensor event listeners that monitor sensor changes

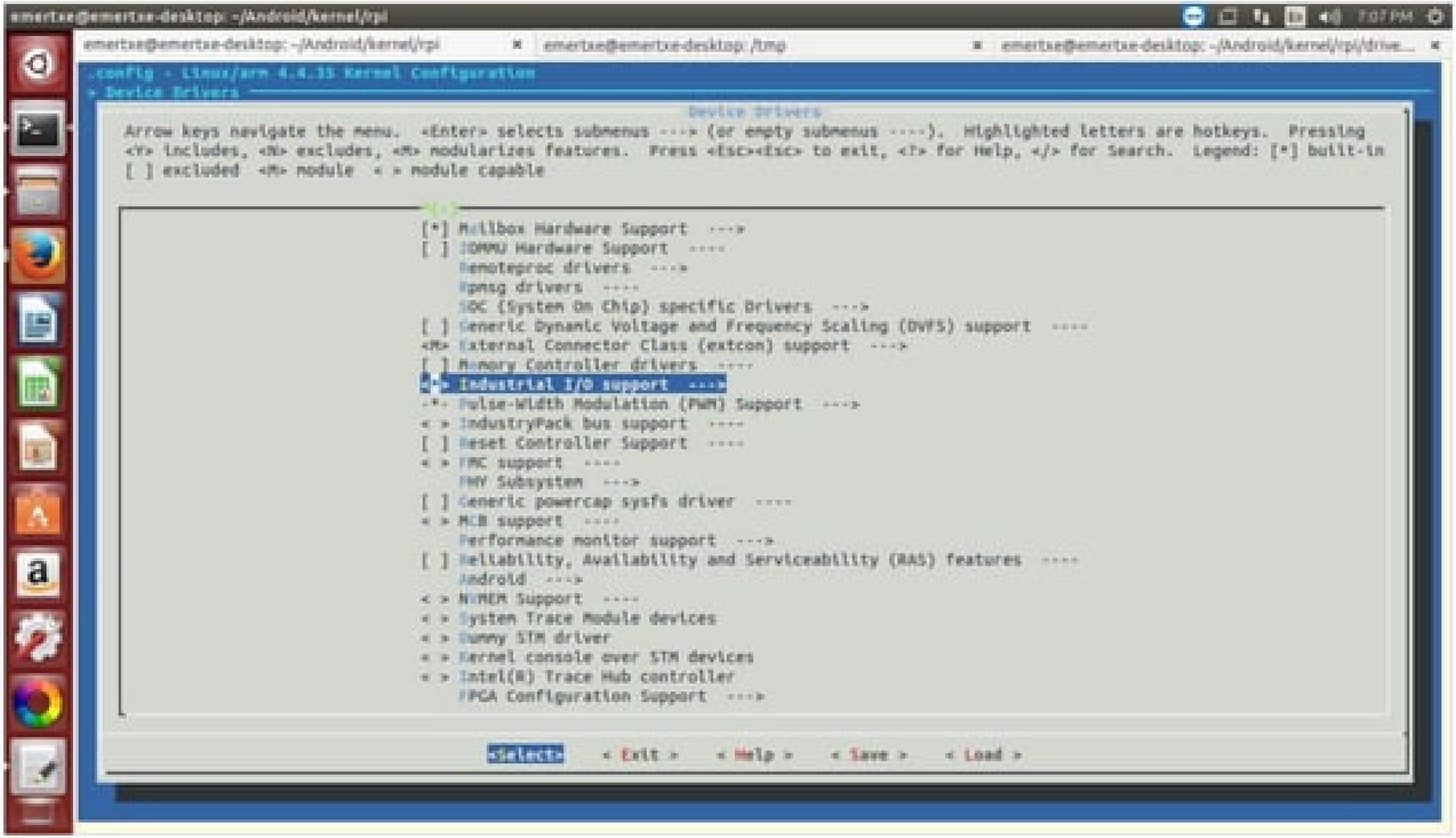
Sensor HAL
(Integration)

- Step 1 – Make sure sensor is enabled in kernel
- Step 2 – Ensure it is functioning in user space
- Step 3 – Create source files, write Android.mk
- Step 4 – Compile code & copy shared library to target
- Step 5 - Test your library with Java app

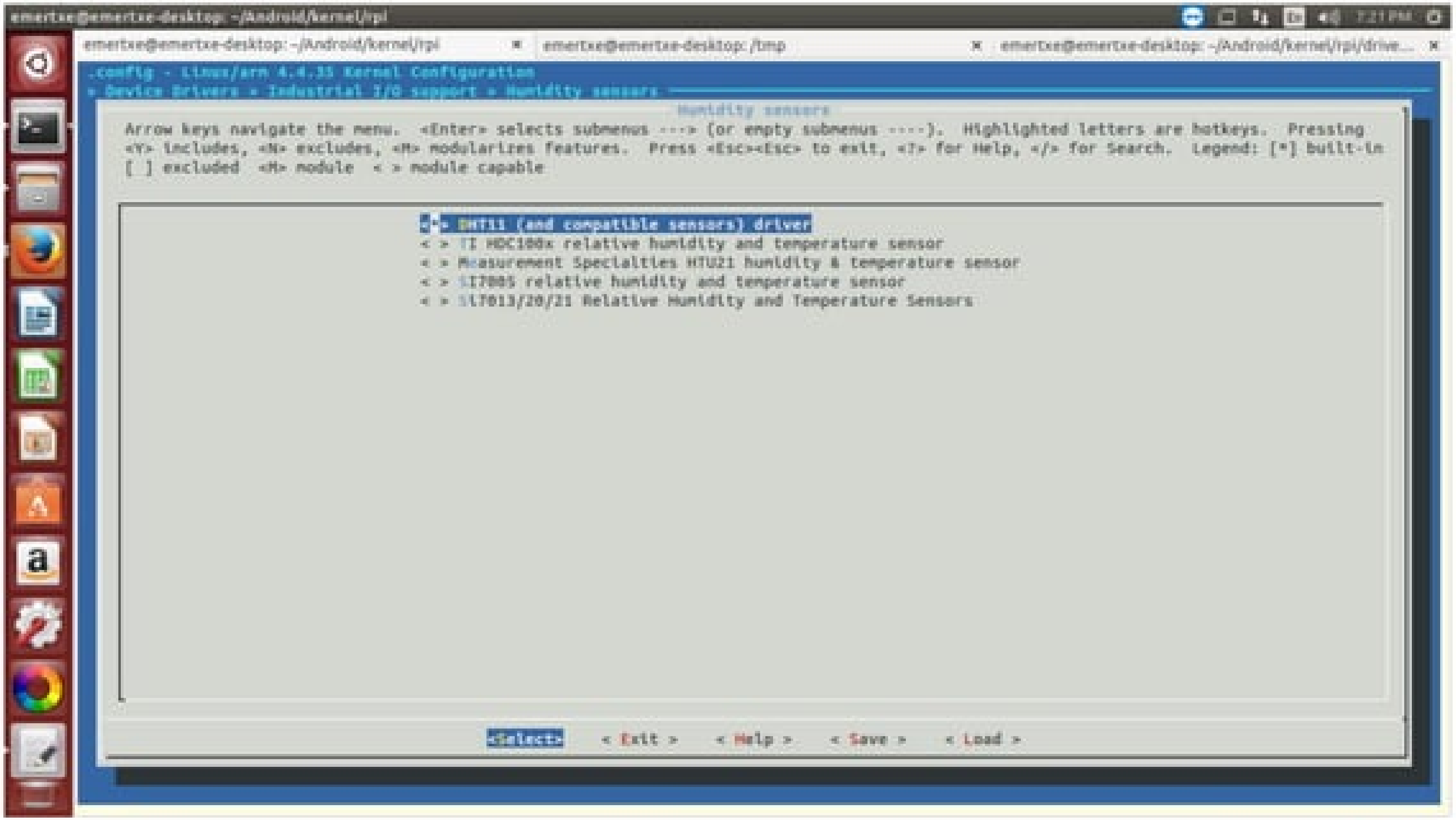
Sensor HAL
(Enable DHT11 in Kernel)

- make ARCH=arm menuconfig
- Add CONFIG_DHT11=y

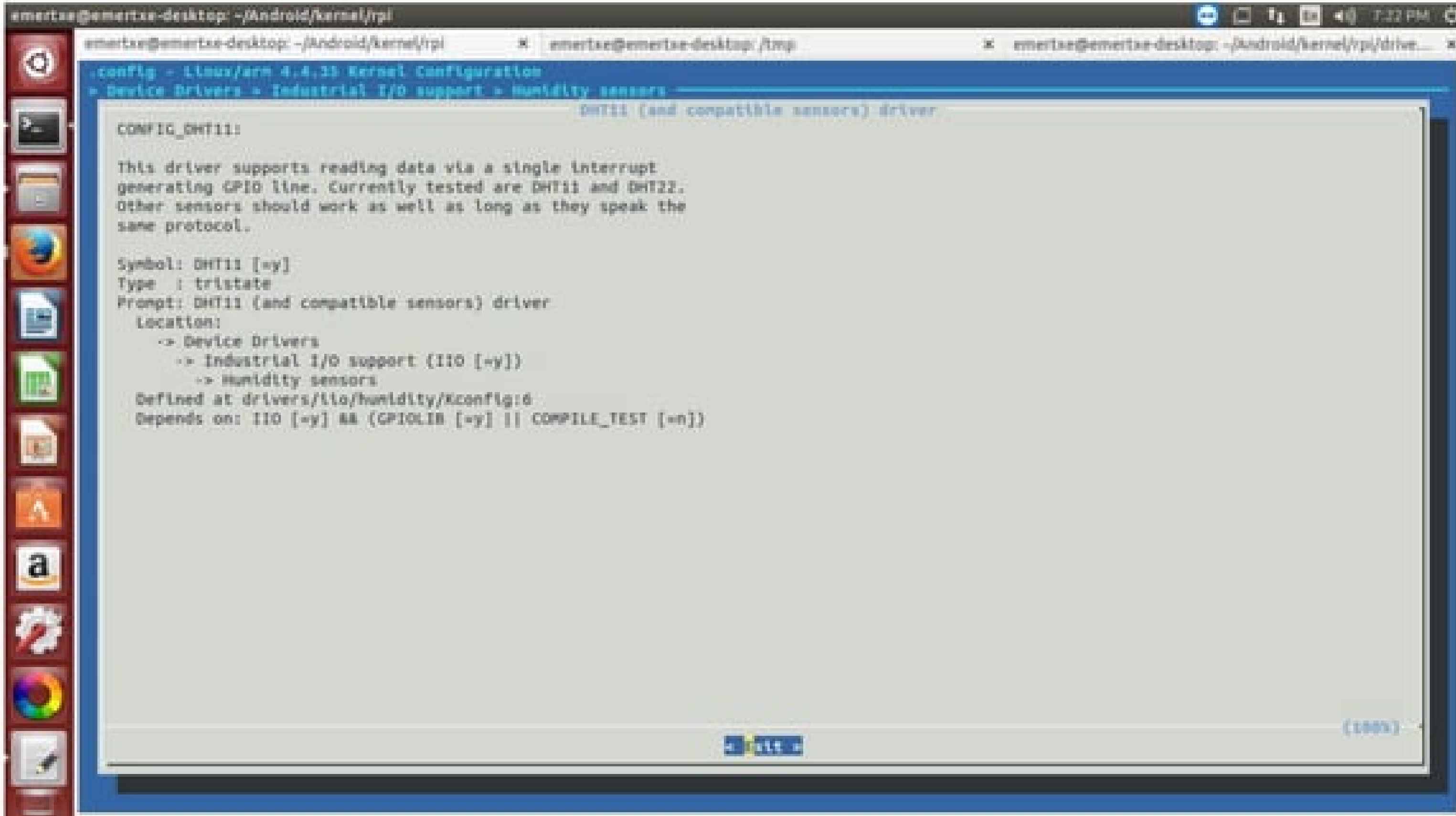
Sensor HAL
(Enable IIO in Kernel)



Sensor HAL
(Enable IIO in Kernel)



Sensor HAL
(Enable IIO in Kernel)



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Sensor HAL
(Boot Configuration)

- Add following line in /boot/config.txt
  - dtoverlay=dht11,gpiopin=4

Sensor HAL
(Industrial IO deriver)

- Device path : /dev/iio:deviceo
- Sysfs path : /sys/bus/iio/devices/iio:deviceo
- Temperature input file – in_temp_input
- Humidity input file - in_humidityrelative_input

Sensor HAL
(Testing stand alone DHT11)

- Use testiio utility program
- Use test-nusensors utility program
  (hardware/libhardware/tests/nusensors/nusensors.cpp)
- Use strace to debug (su mode)

Sensor HAL
(Sensor HAL integration)

- Integrating Intel open source sensor HAL
  - ✓ Copy files in hardware/rpi/
  - ✓ Write Android.mk
  - ✓ Compile files and copy output in /system/lib/hw
  - ✓ Use test-nusensors to test native library
  - ✓ Use Android Studio to test at app level

Sensor HAL
(Sensor Event Mapping)

- Data received from h/w sensor shall be mapped to Android sensor event (sensors_event_t)
- Members of sensors_event_t are as follows

#	Type	Name	Description
1	Integer	version	Set to sizeof sensors_event_t
2	Integer	sensor	Sensor handle (identifier)
3	Integer	type	Sensor Type
4	Integer	reserved	Reserved for future use
5	Integer	timestamp	Time is nano-seconds
6	Union	Sensor members	Used based on type of sensor
7	Integer	flags	Reserved flags (set to zero)
8	Integer	reserved1[3]	For future use

Sensor HAL
(Sequence of calls)

- Device boot up : get_sensors_list is called
- Sensor activation : batch function will be called with the requested parameters, followed by activate(..., enable=1)
  - In HAL version 1_0, the order was the opposite: activate was called first, followed by set_delay
- Activated : batch function is called when requested to change characteristics of a sensor
- flush can be called at any time, even on non-activated sensors (in which case it must return -EINVAL)
- When a sensor gets deactivated, activate(..., enable=0) will be called.
- In parallel to those calls, the poll function will be called repeatedly to request data. poll can be called even when no sensors are activated

Sensor HAL
(Sensor Interface functions)

#	function	Description
1	get_sensor_list (list)	Called at boot up to return implemented sensors by HAL
2	activate (sensor, enable)	To activate/deactivate sensor
3	batch (sensor, flags, sampling period, max report latency)	Sets a sensor's parameters, including sampling frequency and maximum report latency.
4	setDelay (sensor, sampling delay)	Deprecated, used by HAL v1.0
5	flush (sensor)	Flush hardware FIFO and send flush complete event
6	poll ( )	Returns number of events or error. The function shall never return 0.

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THANK YOU