Treble VNDK

Design Principles and Practical Migration

Google

Status

- VNDK is partially implemented in **Android Oreo**
  - Only VNDK-SP (for SP-HAL) is enforced
- VNDK is fully implemented in **Android Oreo-MR1**
  - VNDK-SP (for SP-HAL) is enforced
  - Enabling VNDK is recommended
- In the future, VNDK will be fully enforced and **ineligible libraries won't be accessible by vendor modules at build-time and run-time**

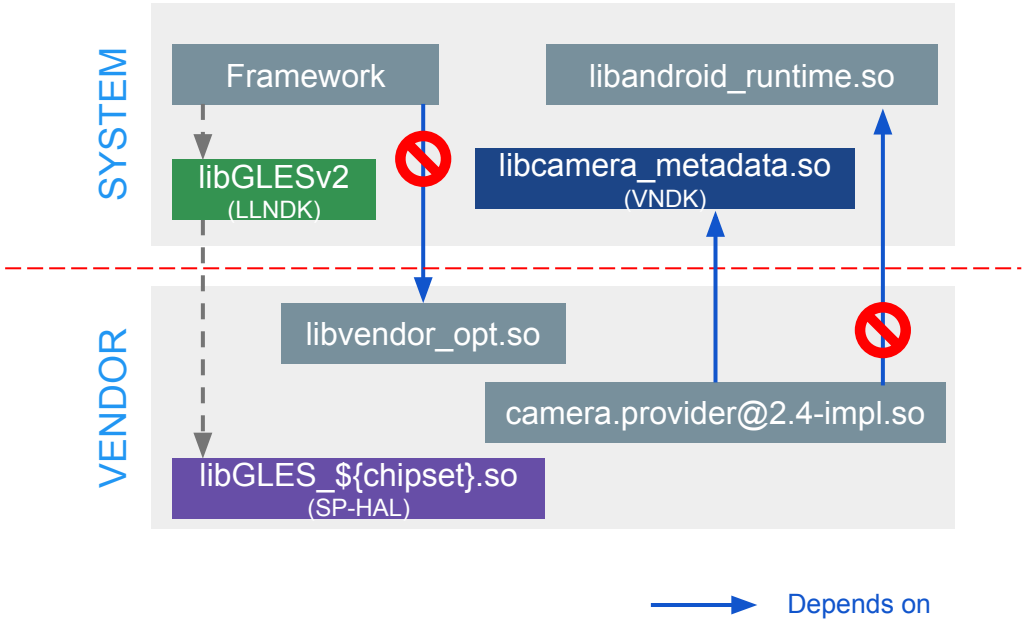
Agenda

- VNDK overview
- Dynamic linker support
- Build system support
- VNDK definition tool
- JNI libraries in bundled APKs

VNDK overview

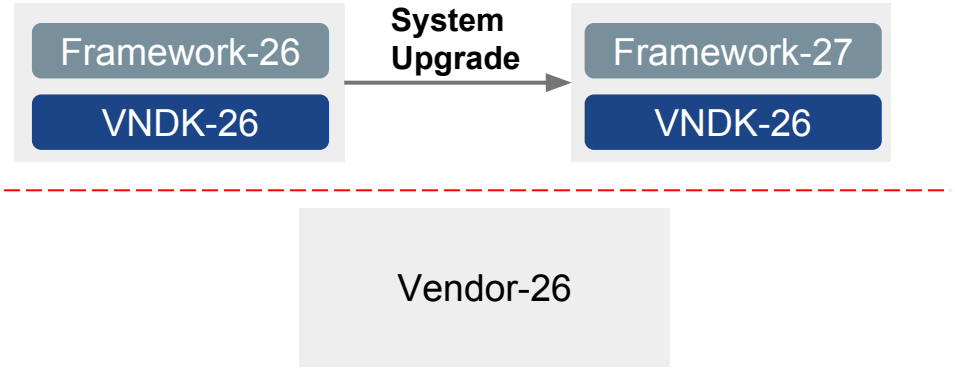
Modular Android -- in view of lib dependency

- Vendor modules should not depend on system modules
  - Except: **VNDK**
- Framework do not depend on vendor modules
  - Except:
    Same-process HAL (**SP-HAL**)



What is VNDK?

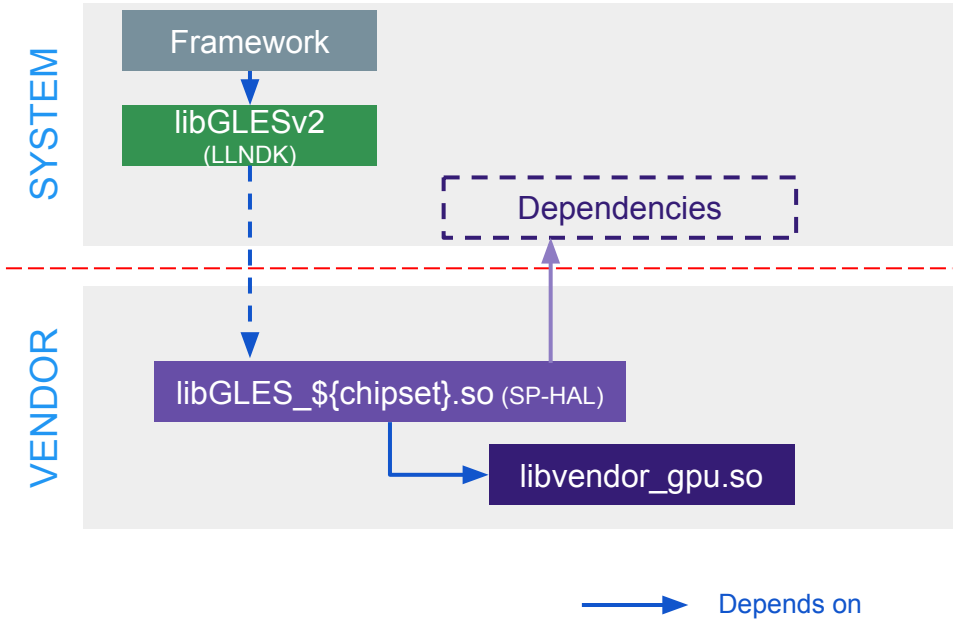
- **VNDK** is a set of shared libraries for vendors to implement vendor modules.
  - Part of VINTF
  - Versioned, stable



Same-Process HAL

- **SP-HAL** -- Several time-critical HALs are not binderized
  - `android.hardware.renderscript@1.0-impl`
  - `android.hardware.graphics.mapper@1.0-impl`
  - `android.hidl.memory@1.0-impl`
  - `libEGL_${chipset}`
  - `libGLES_${chipset}`
  - `vulkan.${chipset}`

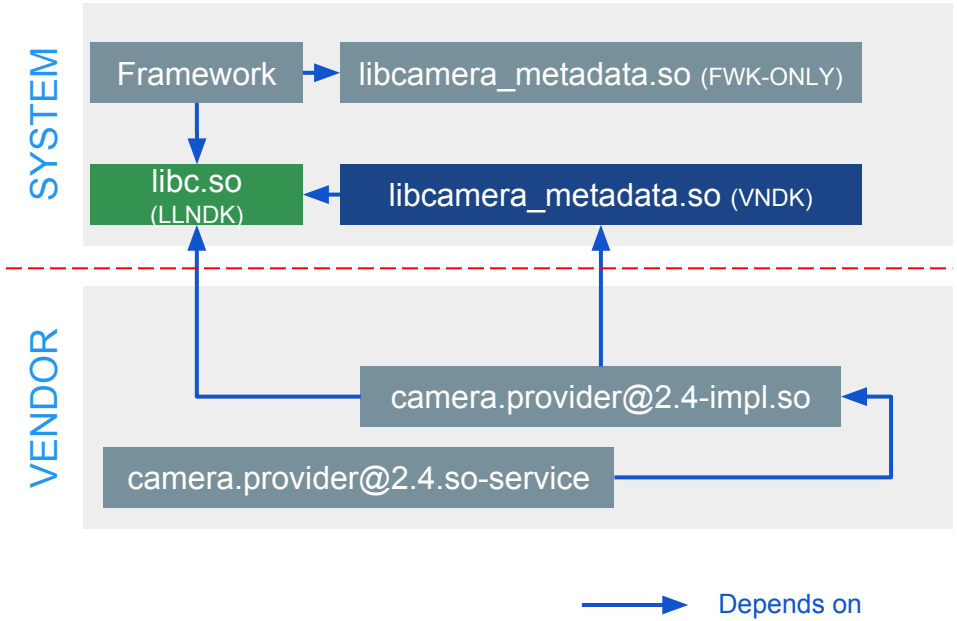
- What about its dependency?



* To be precise, both SP-HAL and their dependencies applies.

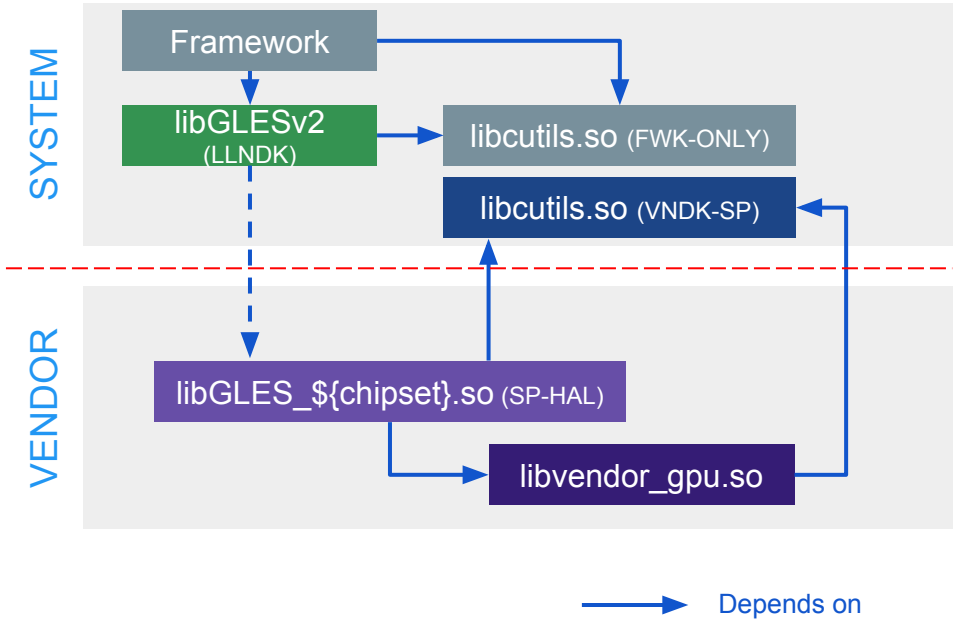
VNDK categories

- **LLNDK** (LL-NDK + SP-NDK)
  - Shared libraries with stable APIs and loosely coupled with the framework
  - Both system and vendor share the same file
- **VNDK**
  - A specialized variant built for vendor modules.
  - There may be a FWK-ONLY counterpart with the same name.
- **VNDK-SP**
  - Same as VNDK
  - Can be used by SP-HALs
  - May be loaded into framework process (to be explained in the next slide and dynamic linker namespace section)



VNDK-SP: Dependency of Same-Process HAL

- SP-HAL must only depend on LLNDK or VNDK-SP*
  - VNDK-SP and its FWK-ONLY counterpart (shared lib with same name) may be loaded into the same process.

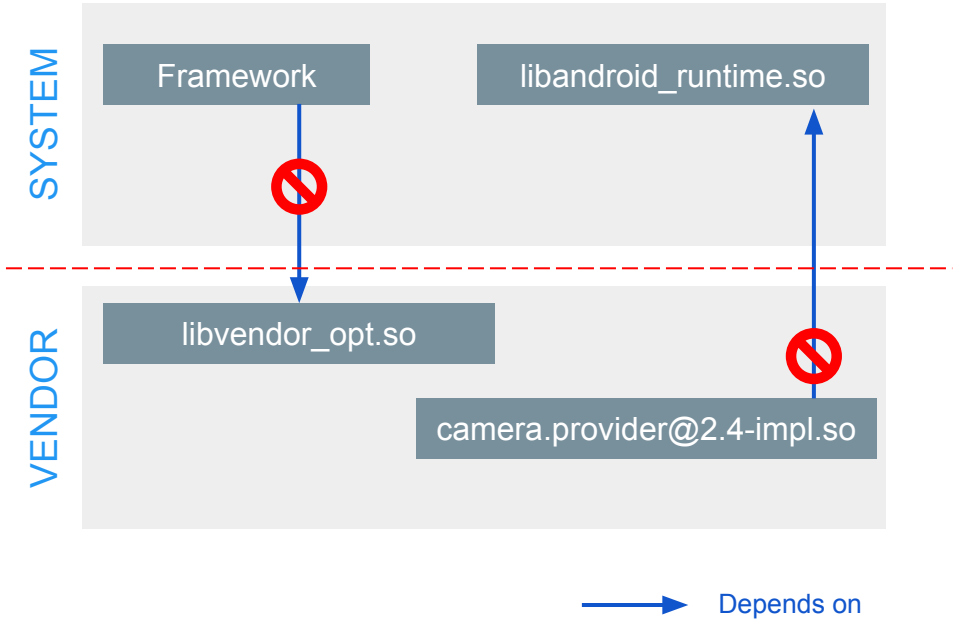


Other categories

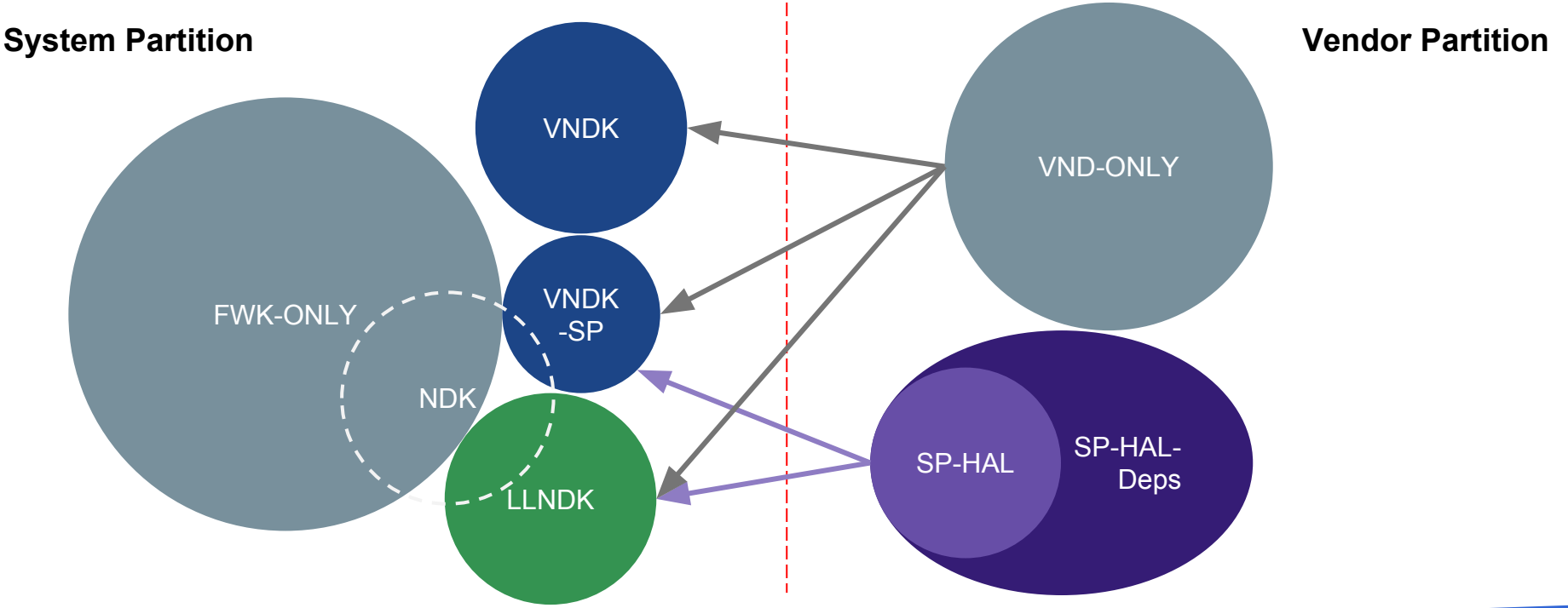
- **FWK-ONLY**
  - Other shared libraries on the system partition
  - Vendor modules must not depend on these libraries
- **VND-ONLY**
  - Other (i.e., non-SP-HAL) shared libraries on the vendor partition
  - Framework modules must not depend on these libraries

Any cross-partition dependencies must be in LLNDK, VNDK, VNDK-SP and SP-HAL.

- This is recommended in O-MR1 and will be enforced in P.



Glimpse of categories 1/3



Glimpse of categories 2/3

The definitive list can be found in /system/etc/ld.config.txt.

LLNDK

libEGL
libGLESv1_CM
libGLESv2
libGLESv3
libRS
libandroid_net#
libc
libdl
liblog
libm
libnativewindow
libsync
libvndksupport#

VNDK-SP

android.hardware.graphics.allocator@2.0
android.hardware.graphics.common@1.0
android.hardware.graphics.mapper@2.0
android.hardware.renderscript@1.0
android.hidl.memory@1.0
android.hidl.memory@1.0-impl
libRSCpuRef
libRSDriver
libRS_internal
libbacktrace
libbase
libbcinfo
libblas
libc++
libcompiler_rt
libcutils
libhardware
libhidlbase
libhidlmemory
libhidltransport
libhwbinder
libion
liblzma
libunwind
libunwindstack
libutils
libz*

* In some configurations, libz belongs to LLNDK but there should be no differences.
# These are LLNDK but not NDK.

Glimpse of categories 3/4

- **Eligible list** is a list of shared libraries that have been reviewed.
  - Can be found in: `${AOSP}/development/vndk/tools/definition-tool/datasets/eligible-list*.csv`

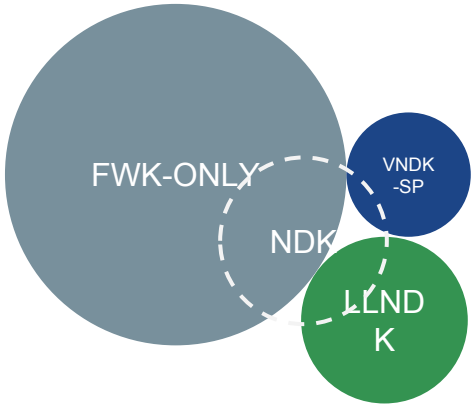
Glimpse of categories 4/4

Some NDK libs not visible to vendor modules

libandroid.so
libaaudio.so
libcamera2ndk.so
libicui18n.so
libicuuc.so
libjnigraphics.so
libmediandk.so
libneuralnetworks.so
libOpenMAXAL.so
libOpenSLES.so
libstdc++.so*
libvulkan.so
libwebviewchromium_plat_support.so

These libraries are **highly coupled** with the framework, thus they do not belong to LLNDK.

Vendor modules must **not** depend on these shared libraries.



* Use libc++ instead of libstdc++.

VNDK extension 1/2

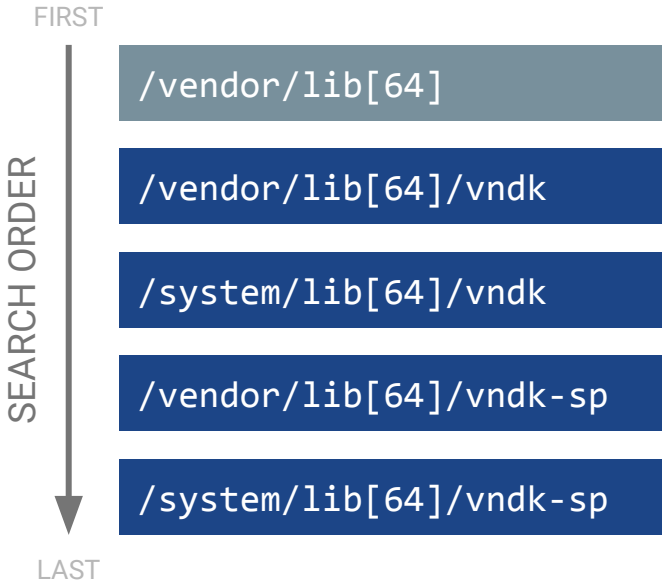
- Vendor modules may need **extra APIs** or **extra functionalities** from the VNDK libraries.
- VNDK can be extended, but they must remain **ABI compatible** to the AOSP VNDK.
  - Symbols must not be removed.
  - Exposed structures must not be altered (including struct/class layout and vtable)
  - **The idea is to make sure all extensions are drop-in replacements of the AOSP VNDK shared libraries.**

```
struct Example {
  int a_;
  int bias_;
};

Example *example_create(int a) {
  Example *e = (Example *)malloc(sizeof(Example));
  e->a_ = a;
  e->bias_ = rand();
  return e;
}

int example_get_a(Example *e) {
  return e->a_ + e->bias_;
}
```

```
/* Extensions */
void example_set_bias(Example *e, int b) {
  e->bias_ = b;
}
```

VNDK extension 2/2

- Extended VNDK libraries must be installed into `/vendor/lib[64]/{,vndk,vndk-sp}`
  - Otherwise, vendor modules will fail **VTS** tests on **GSI**, which is required to pass compliance.
  - Use this as a **last resort** because extended VNDK shared libraries are not framework-only OTA updatable.
  - **VNDK definition tool** can provide some preliminary set (will be introduced later)



Degenerated VNDK (O) vs. Treble VNDK (O-MR1)

In **Android O**, **degenerated VNDK directory layout** is adopted:

- VNDK-SP libraries have extra copies in `/system/lib[64]/vndk-sp`
- Both framework and vendor modules are using shared libraries in `/system/lib[64]`

In **Android O-MR1**, **Treble VNDK directory layout** is adopted:

- VNDK-SP libraries have extra copies in `/system/lib[64]/vndk-sp`
- VNDK libraries have extra copies `/system/lib[64]/vndk`
- Vendor modules are only using `/system/lib[64]/{vndk,vndk-sp}`
- Framework modules are only using `/system/lib[64]`

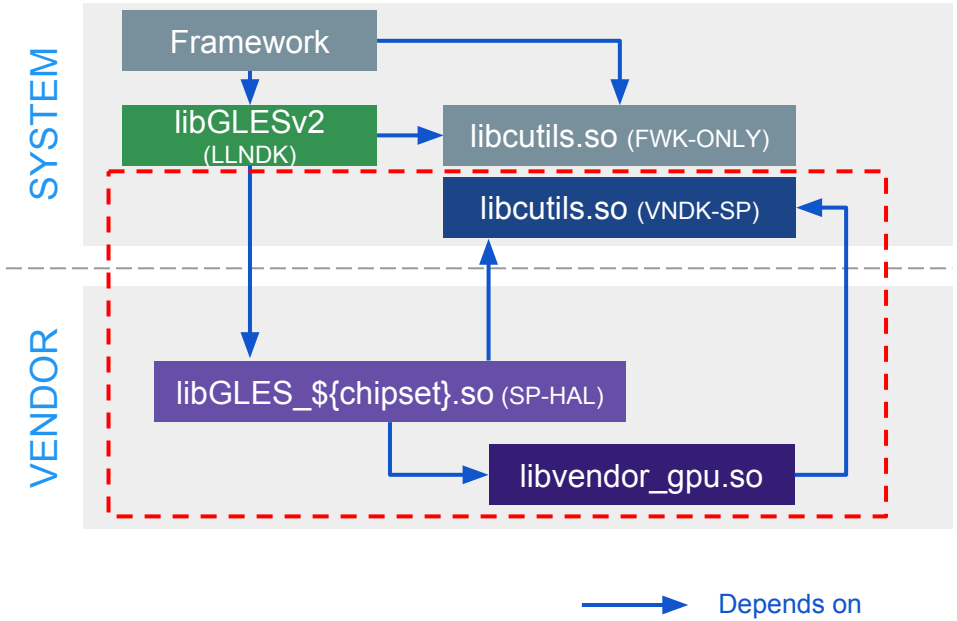
Directory layout

	Android O	Android O-MR1	Independent system updates
FWK-ONLY	`/system/lib[64]`	`/system/lib[64]`	Everything may change
LLNDK	`/system/lib[64]`	`/system/lib[64]`	New APIs or implementation
VNDK-SP	`/system/lib[64]/vndk-sp`	`/system/lib[64]/vndk-sp`	Old APIs with security fixes
VNDK-SP-EXT	`/vendor/lib[64]/vndk-sp`	`/vendor/lib[64]/vndk-sp`	N/A
VNDK	`/system/lib[64]` (degenerated)	`/system/lib[64]/vndk`	Old APIs with security fixes (only O-MR1)
VNDK-EXT	`/vendor/lib[64]`	`/vendor/lib[64]/vndk`	N/A
VND-ONLY	`/vendor/lib[64]`	`/vendor/lib[64]`	N/A

Dynamic linker support

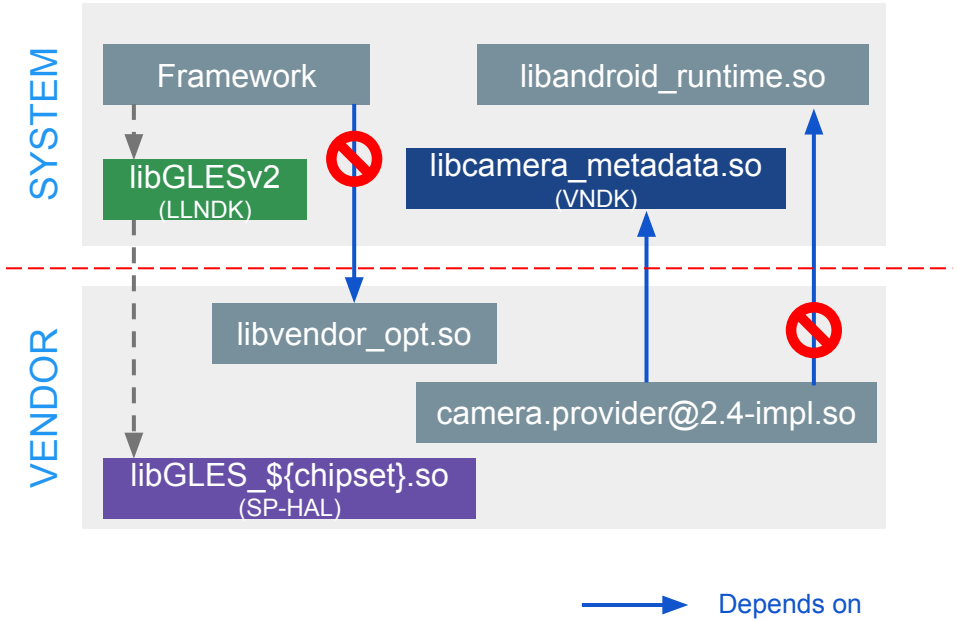
Motivation: Isolate SP-HAL and VNDK-SP 1/2

- SP-HAL from the vendor partition will be loaded into framework processes.
- SP-HAL may depend on **VNDK-SP**.
- Framework modules may depend on **FWK-ONLY counterpart** (shared lib with same name with VNDK-SP).
- Loading two shared libraries with the same soname causes some problems.
  - They may have different symbols after updates.
- Enforced in Android Oreo (`PRODUCT_FULL_TREBLE:=true`)



Motivation: Isolate system and vendor 2/2

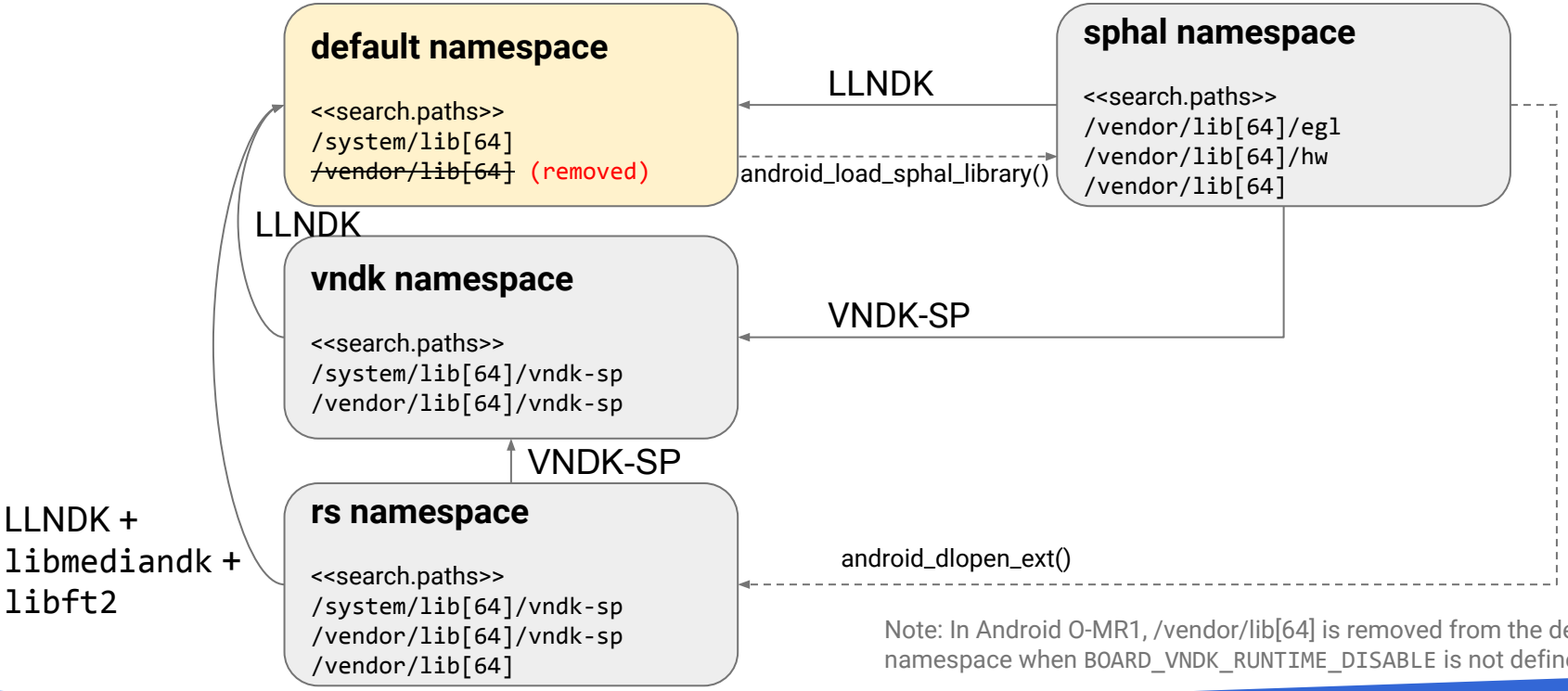
- Isolate the shared library dependencies
  - Dynamic linker should not load shared libraries from the other partition except VNDK or SP-HAL.
- Requirement
  - Not in **Oreo**
  - Recommended in **Oreo-MR1**
  - Enforced in **Pi**
- In Oreo-MR1, if BOARD_VNDK_VERSION is specified, then this will be enforced by default.
  - To disable this, add `BOARD_VNDK_RUNTIME_DISABLE:=true`



Dynamic linker namespace

- **Dynamic linker** `/system/bin/linker[64]` is a part of Bionic that loads and links ELF shared objects at run-time.
  a. It is the first program being run after the kernel maps the executable into memory.
  b. It is responsible to load `DT_NEEDED` entries and resolve undefined symbols.
  c. It implements `dlopen()` and `android_dlopen_ext()`.
- **Dynamic linker namespace** is a mechanism to
  a. Isolate shared libraries
  b. Provide fine-grained control on dynamic **shared libraries** resolution
  c. Provide fine-grained control on **symbol** resolution
- Dynamic linker namespace is the underlying mechanism to **isolate SP-HALs and VNDK-SP**.

Framework process linker namespaces (Oreo-MR1)



Note: In Android O-MR1, /vendor/lib[64] is removed from the default linker namespace when `BOARD_VNDK_RUNTIME_DISABLE` is not defined.

Vendor process linker namespaces (Oreo)

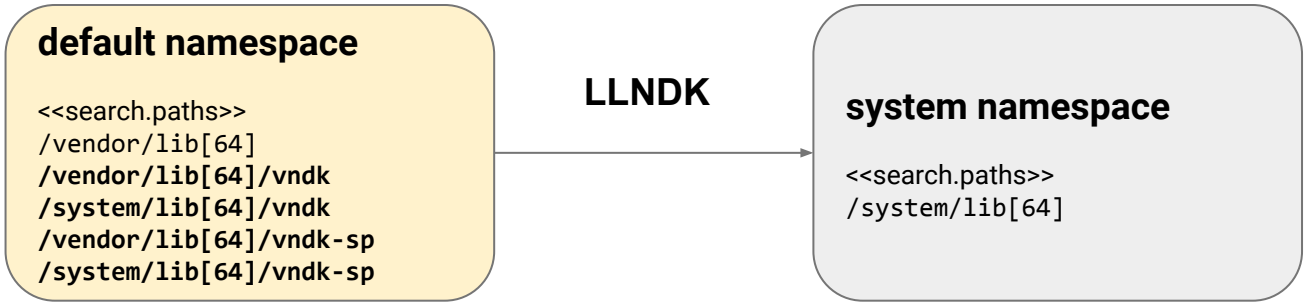
default namespace

<<search.paths>>
/vendor/lib[64]
/system/lib[64]

Note: `/system/lib[64]` is in the default linker namespace of vendor processes in Android O.

However, it will be *removed* in O-MR1 if `BOARD_VNDK_RUNTIME_DISABLE` is not defined.

Vendor process linker namespaces (Oreo-MR1)



Note: `/system/lib[64]` will be *removed* from the default linker namespace of vendor processes in Android O-MR1 if `BOARD_VNDK_RUNTIME_DISABLE` is not defined.

ld.config.txt 1/4

- Dynamic linker namespace is configured by `/system/etc/ld.config.txt`
  - **INI file format**
  - Source code is at `${AOSP}/system/core/rootdir/etc/ld.config*.txt`
- `ld.config.txt` must **not be modified**.
  - There will be a CTS checking whether this file is intact.
  - However, learning the file format can help understanding how does VNDK work.

ld.config.txt: General structure 2/4

- `dir.name` assignments specify the section which will be chosen.
  - For example, `[system]` section will be chosen if the main executable of the process resides in `/system/bin`.
- Each section represents a graph with (1) several **linker namespaces** as nodes and (2) several links for **fallback lookups**.

```
dir.system = /system/bin
dir.vendor = /vendor/bin

[system]
additional.namespaces = sphal,vndk,rs

namespace.default.isolated = true
namespace.default.search.paths = ...
namespace.default.permitted.paths = ...

namespace.sphal.isolated = true
namespace.sphal.visible = true
namespace.sphal.search.paths = ...
namespace.sphal.permitted.paths = ...
namespace.sphal.link.default.shared_libs =

[vendor]
```

ld.config.txt: Namespace properties 3/4

For each section

- **`additional.namespaces`** specifies the names of other linker namespace in addition to the default namespace.

For each linker namespace

- **`isolated`** specifies whether `permitted.paths` is enforced
- **`permitted.paths`** specifies the permitted path (in addition to `search.paths`) when `isolated` is true.
- **`search.paths`** specifies the directories which will be search for when dynamic linker is resolving an *soname**.
- **`visible`** specifies whether the namespace can be found by `android_get_exported_namespace()`

```
dir.system = /system/bin
dir.vendor = /vendor/bin

[system]
additional.namespaces = sphal,vndk,rs

namespace.default.isolated = true
namespace.default.search.paths = ...
namespace.default.permitted.paths = ...

namespace.sphal.isolated = true
namespace.sphal.visible = true
namespace.sphal.search.paths = ...
namespace.sphal.permitted.paths = ...
namespace.sphal.link.default.shared_libs =

[vendor]
```

* If someone pass a full path to dlopen(), then `search.paths` is irrelevant.

ld.config.txt: Fallback links 4/4

- `namespace.${name}.link.${another}.shared_libs` specifies the *soname* that can go through the fallback link to the linker namespace `${another}`.
  - If an *soname* cannot be resolved in linker namespace `${name}` and the *soname* is one of the property value, then the dynamic linker will try to resolve the soname in the linker namespace `${another}`.
  - For example, if `/vendor/lib/hw/vulkan.${chipset}.so` depends on `libc.so` but `libc.so` is neither in `/vendor/lib/hw` nor `/vendor/lib`, thus the dynamic linker will try to find `libc.so` in the `default` namespace.

```
dir.system = /system/bin

[system]
additional.namespaces = sphal,vndk,rs

namespace.default.search.paths =
    /system/${LIB}

namespace.sphal.search.paths =
    /vendor/${LIB}/hw:/vendor/${LIB}

namespace.sphal.link.default.shared_libs =
    libc.so:libm.so
```

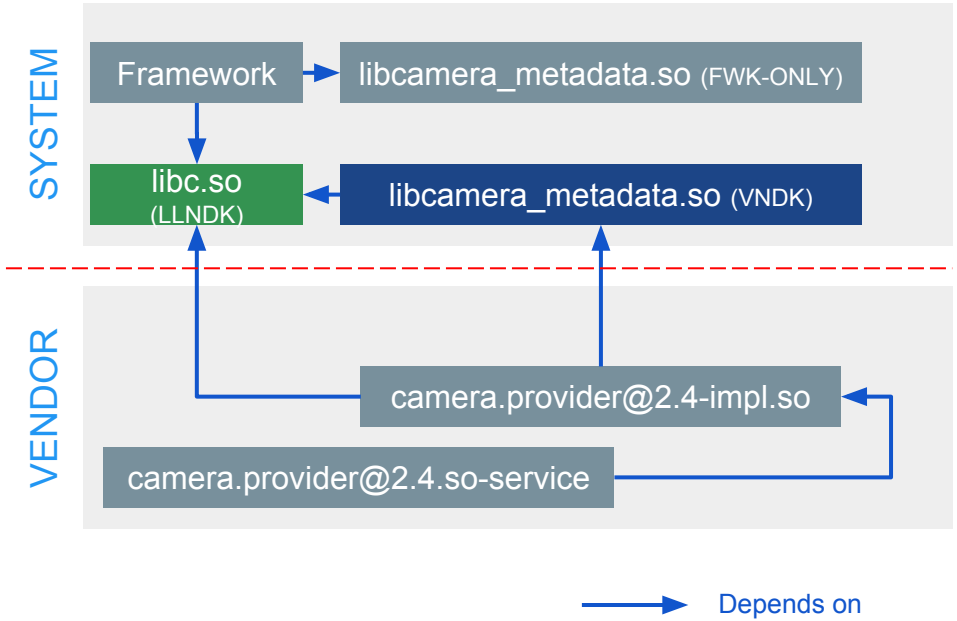
Build system support

Motivations

- **Duplicate shared libraries when necessary**
  - Build vendor variant for users in vendor partitions
  - VNDK, VNDK-SP may be duplicated when needed
- **Make the build dependencies explicit**
  - Check whether headers, static libraries, shared libraries are available
  - Define the VNDK libraries that have to be installed into GSI
  - Generate VNDK snapshots for cross version system image development

Recap: VNDK categories

- **LLNDK** (LL-NDK + SP-NDK)
  - Shared libraries with stable APIs and loosely coupled with the framework
  - Both system and vendor share the same file
- **VNDK**
  - A specialized variant built for vendor modules.
  - There may be a FWK-ONLY counterpart with the same name.
- **VNDK-SP**
  - Same as VNDK
  - Can be used by SP-HALs
  - May be loaded into framework process (to be explained in the next slide and dynamic linker namespace section)



Build system support (Oreo)

- To move a module to vendor partition:
  - Add **`LOCAL_VENDOR_MODULE:=true`** to Android.mk (or `LOCAL_PROPRIETARY_MODULE`)
  - Add **`vendor:true`** to Android.bp (or `proprietary`)
- To install a module to **both system and vendor partitions**, you will need tricky build rules on the right or in the document
  - Basically, this trick assigns *intermediate files* to `LOCAL_PREBUILT_MODULE_FILE`.

```
define define-vndk-lib
include $$(CLEAR_VARS)
LOCAL_MODULE := $1.$2
LOCAL_MODULE_CLASS := SHARED_LIBRARIES
LOCAL_PREBUILT_MODULE_FILE := $$(TARGET_OUT_INTERMEDIATE_LIBRARIES)/$1.so
LOCAL_STRIP_MODULE := false
LOCAL_MULTILIB := first
LOCAL_MODULE_TAGS := optional
LOCAL_INSTALLED_MODULE_STEM := $1.so
LOCAL_MODULE_SUFFIX := .so
LOCAL_MODULE_RELATIVE_PATH := $3
LOCAL_VENDOR_MODULE := $4
include $$(BUILD_PREBUILT)

ifneq ($$(TARGET_2ND_ARCH),)
ifneq ($$(TARGET_TRANSLATE_2ND_ARCH),true)
include $$(CLEAR_VARS)
LOCAL_MODULE := $1.$2
LOCAL_MODULE_CLASS := SHARED_LIBRARIES
LOCAL_PREBUILT_MODULE_FILE :=
$$($$(TARGET_2ND_ARCH_VAR_PREFIX)TARGET_OUT_INTERMEDIATE_LIBRARIES)/$1.so
LOCAL_STRIP_MODULE := false
LOCAL_MULTILIB := 32
LOCAL_MODULE_TAGS := optional
LOCAL_INSTALLED_MODULE_STEM := $1.so
LOCAL_MODULE_SUFFIX := .so
LOCAL_MODULE_RELATIVE_PATH := $3
LOCAL_VENDOR_MODULE := $4
include $$(BUILD_PREBUILT)
endif  # TARGET_TRANSLATE_2ND_ARCH is not true
endif  # TARGET_2ND_ARCH is not empty
endef
```

Build system support (Oreo-MR1) 1/4

- “**`BOARD_VNDK_VERSION := current`**” enables full VNDK support.
- If “`BOARD_VNDK_VERSION := current`” is specified in `BoardConfig.mk`, then build system will:
  - Check the header search path (and removes global default search paths)
  - Check the link types of the shared libraries (i.e. vendor module can only either link to LLNDK or vendor_available)
  - Build vendor-specific VNDK libraries and install them to `/system/lib[64]/{vndk,vndk-sp}`
  - Build vendor-specific libraries and install them to `/vendor/lib[64]`
- VNDK-related properties in Android.bp:
  - `vendor: true`
  - `vendor_available: true`
  - `vndk.enabled: true`
  - `vndk.support_system_process: true`

Build system support (Oreo-MR1) 2/4

- `vendor` specifies whether an Android.bp module is an vendor module or not.
  - If this value is false, then it can not depend on the module with `vendor` equals to true.
  - If this value is true, then it can only depend on LLNDK or the module with `vendor_available` equals to true.
- `vendor_available` specifies whether an Android.bp module (header lib, static lib, or shared lib) is available to vendor.
  - If this value is true and a **framework module** uses this module, then this module will be installed into the system partition.
  - If this value is true and a **vendor module** uses this module, then the vendor variant will be built. If `vndk.enabled` is false (or not defined), then this will be installed to `/vendor/lib[64]`; otherwise, this module will be installed to `/system/lib[64]/vndk` or `/system/lib[64]/vndk-sp`.

Build system support (Oreo-MR1)

- **vndk section**
  - `vndk.enabled` specifies whether an Android.bp module is a VNDK library or not. It is a prerequisite to set `vendor_available` to true.
  - `vndk.support_system_process` specifies whether an Android.bp module is a VNDK-SP library or not. Both `vendor_available` and `vndk.enabled` are prerequisites.

```
cc_library {
    name: "libvendor_available",
    vendor_available: true,
}
cc_library {
    name: "libvndk",
    vendor_available: true,
    vndk: {
        enabled: true,
    },
}
cc_library {
    name: "libvndksp",
    vendor_available: true,
    vndk: {
        enabled: true,
        support_system_process: true,
    },
}
```

Build system support (Oreo-MR1) 4/4

- **`target.vendor`** specifies vendor-specific build options.
  - Use the **exclude_srcs** property if you would like to exclude framework-specific source files.
  - Use the **`exclude_shared_libs`** property if you would like to exclude framework-specific shared libraries.

```
cc_library {
  name: "libvnd_specific_example",
  vendor_available: true,
  target: {
    vendor: {
      exclude_srcs: ["framework_only.c"],
      exclude_shared_libs: ["libfwk_only"],
      cflags: ["-DEXTRA_VND_C_FLAGS"],
      cppflags: ["-DEXTRA_VND_CPP_FLAGS"],
    },
  },
}
```

Sum up

- Define a vendor module which must be installed to vendor partition
  - `LOCAL_VENDOR_MODULE := true` (Android.mk)
  - `vendor: true` (Android.bp)
- Enable full VNDK build-time support (O-MR1)
  - `BOARD_VNDK_VERSION := current` (BoardConfig.mk)
  - Build two variants: `vendor_available: true`
  - VNDK: `vndk.enabled: true`
  - VNDK-SP: `vndk.support_system_process: true`
- Disable run-time dynamic linker isolation between framework and vendor (O-MR1)
  - `BOARD_VNDK_RUNTIME_DISABLE := true` (BoardConfig.mk)

VNDK definition tool

VNDK definition tool

- **VNDK definition tool** scans the shared library dependencies, computes VNDK sets, and checks the existence of dependency violations.
  - Source: ${AOSP}/development/vndk/tools/definition-tool/vndk_definition_tool.py

VNDK definition tool - commands

- `vndk` -- List VNDK libraries and other libraries that should be copied to vendor partitions.
- `check-dep` -- Check whether there are violations in the shared library dependencies.

- `deps` -- Print all resolved dependencies of shared libraries.
- `deps-insight` -- Create a HTML to show the shared library dependencies.

VNDK definition tool: vndk command

- **vndk** command lists VNDK-SP libraries and other libraries that should be copied to vendor partitions.
- Command line options:
  - **--system**: Path to your system partition directory
  - **--vendor**: Path to your vendor partition directory
  - **--aosp-system**: Path to GSI system partition directory. Convert image with simg2img then mount the image.
  - **--tag-file**: Path to eligible list CSV file
  - **--load-extra-deps**: Path to a file specifies extra shared library dependencies.
  - **--full**: List all categories (for debugging)

```
vndk_definition_tool.py vndk \
  --system path/system \
  --vendor path/vendor \
  --aosp-system path/gsi/system \
  --tag-file eligible-list.csv \
  --load-extra-deps deps.txt
```

```
vndk_sp:
/system/lib/vndk-sp/libcutils.so

vndk_sp_ext:
/vendor/lib/vndk-sp/libion.so

extra_vendor_libs:
/vendor/lib/libvendor.so
```

VNDK definition tool: check-dep command

- **`check-dep`** command checks the dependencies and list the violating shared libraries and symbols.
- Command line options: (in addition to vndk command)
  - **`--module-info`**: Path to ${ANDROID_PRODUCT_OUT}/module-info.json
- For each violations, following information will be printed:
  - Violating module and its source path
  - Ineligible dependencies and its source path
  - The imported symbols from the ineligible dependencies.

```
vndk_definition_tool.py check-dep \
  --system path/system \
  --vendor path/vendor \
  --aosp-system path/gsi/system \
  --tag-file eligible-list.csv \
  --load-extra-deps deps.txt \
  --module-info module-info.json
```

```
/vendor/lib/libviolating.so
    MODULE_PATH: libviolating/source
    /system/lib/libineligible1.so
        MODULE_PATH: ineligible1/source
        symbol_a
        symbol_b
    /system/lib/libineligible2.so
        MODULE_PATH: ineligible2/source
        symbol_c
```

VNDK definition tool: deps and deps-insight command

- **deps** and **deps-insight** are debugging commands which will print all dependencies of shared libraries.
  - `deps` prints plain text output
  - `deps-insight` generates HTML for interactive investigation.
- Command line options are similar to `vndk/check-dep` command.

```
vndk_definition_tool.py deps \
  --system path/system \
  --vendor path/vendor \
  --load-extra-deps deps.txt \
  --module-info module-info.json
```

```
vndk_definition_tool.py deps-insight \
  --system path/system \
  --vendor path/vendor \
  --aosp-system path/gsi/system \
  --tag-file eligible-list.csv \
  --load-extra-deps deps.txt \
  --module-info module-info.json
```

JNI libraries in bundled APKs

JNI libraries in bundled apps (O-MR1)

Shared libraries location	**Bundled system app** `/system/app`	**Bundled vendor app** `/vendor/app`	**Downloaded app** `/data/app`
`/system/lib[64]`	All	/system/etc/public.libraries.txt (NDK) + LLNDK	/system/etc/public.libraries.txt (NDK)
`/vendor/lib[64]`	/vendor/etc/public.libraries.txt	All	/vendor/etc/public.libraries.txt
`/system/lib[64]/vndk-sp`	x	Public VNDK-SP	x
`/system/lib[64]/vndk`	x	x	x

Q&A

Full Documentation:
https://source.android.com/devices/architecture/vndk/

Q & A

If you have more questions, please talk to your Technical Account Manager, 3PL or SoC POC. You may also contact us at: android-treble-questions@google.com