

# Linux on Mobile Devices

Last Mile from Mobile Linux to the User

Installfest  
16 March 2025

# Who I am?

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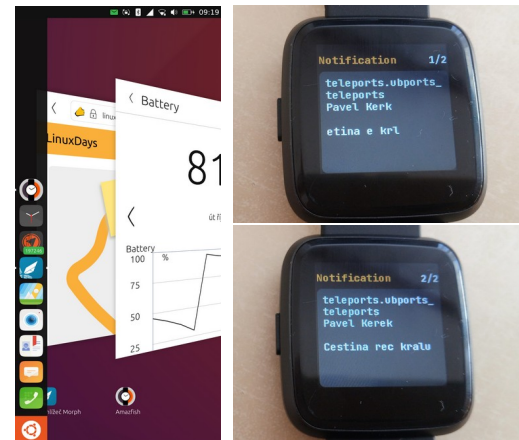
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# Outline

- Motivation
- Alternative operating systems
- Where to get hardware
- Architecture of mobile operating system
- Development
- Demo

# Motivation



openmoko

neo

# Motivation

- Do it your self
  - learn something
- Special needs
  - Create new concept / add some extra feature / very special hardware
- Security
  - how we can trust to Chinese/Russian/US/\* product?
- Longevity
  - security updates are available ~ 2 – 6 years depending on vendor
- Vendor lock-in
  - US Export laws
- Privacy
  - Is that paranoia?



17:33

1:32 PM

3:51 pm

100%

3:54 pm

Search...

postmarketOS

A real Linux distribution for phones

blog faq wiki src

podcast

@postmarketOS

donate

For more info visit our website

Label: name: 021 98 514

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ABOUT

- Places
- Home
  - Downloads
  - Documents
  - Pictures
  - Music
  - Videos
  - Trash
  - Devices
  - System

Buttons

Calculator

Calendar

Camera

Clock

Contacts

External Drive

Media Player

Messaging

Morph Browser

Music

Notes

OpenStore

Phone

System Settings

Terminal

URBeats

Weather

3:51 pm

Wed, Aug 31

- Calindori
- Weather
- Settings
- Terminal
- Clock
- Angelfish
- Media

Tracks

Sort: Title

- Mameyudoufu - Ou...
- Replica
- Lime - Replica
- Skies
- Mameyudoufu - So...
- SOBOK
- Mameyudoufu - MF...
- Spirit Of The Lill...
- Lockyn - Lilyse Vol...
- Stellar
- M2U - Stellar
- Sunbeam Skies
- Lockyn - Sunbeam S...
- Temptation
- M2U - Temptation
- The Queen
- M2U - The Queen
- The Queen (Rhy...
- M2U - The Queen (F...
- The Show Goes o...
- Spirit Of The Li...
- Lockyn

# Software

Search apps...

Phone

Messages

Mail

Firefox

Calculator

Clocks

Image Viewer

Lollypop

Megapixels

Portfolio

Settings

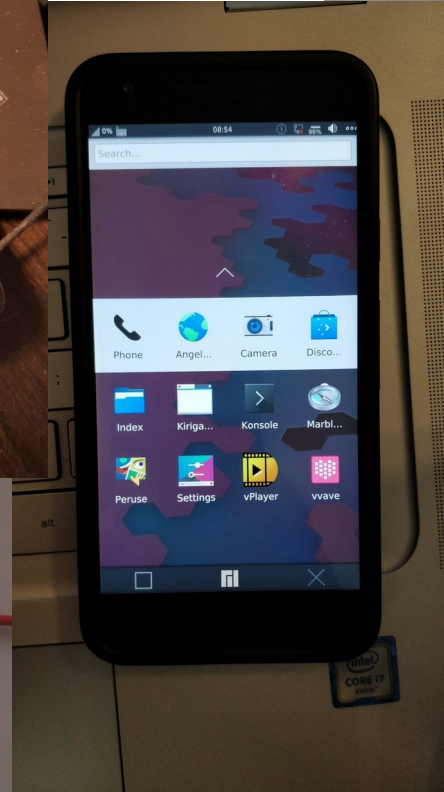
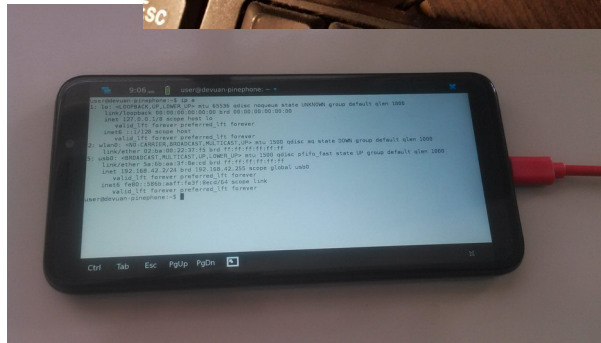
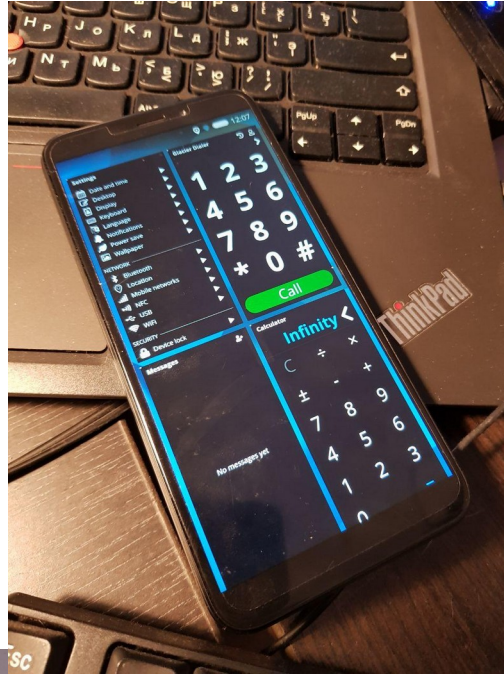
Software

# Distributions

- postmarketOS
- Ubuntu Touch (20.04 OTA-8)
- Maemo Leste
- SailfishOS
- PureOS
- DahliaOS
- Fedora, Arch Linux ARM, Manjaro ARM, Mobian
- AsteroidOS
- LineageOS, /e/, CalyxOS, GrapheneOS, Replicant, Copperhead, AOSP
- Nemo Mobile
- KDE Neon
- Capyloon (FirefoxOS)
- NixOS
- LuneOS
- Sxmo
- openSUSE
- AVMultiPhone
- GloDroid
- Gentoo
- Tizen

# Desktop Environments / UX

- Lomiri
- Phosh
- Plasma Mobile
- Maemo
- Glacier (Nemo)
- SMXO
- Android
- ...







**Hardware**

# Hardware

Device	Codename	Architecture	Release year	USB Net	Flashing	Touch	Screen	Wifi	FDE	Battery	3D	IMU	Audio	Bluetooth	Camera	GPS	Mobile Data	SMS	Calls	USB-OTG	NFC
BQ Aquaris X5	bq-paella	aarch64	2015	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	-
Fairphone 4	fairphone-fp4	aarch64	2021	Y	Y	Y	Y	Y	Y	N	Y	Y	N	Y	N	N	Y	Y	P	Y	N
Google Pixel 3a	google-sargo	aarch64	2019	Y	Y	Y	Y	P	Y	P	Y	Y	P	Y	P	N	Y	Y	P	N	P
Lenovo A6000	lenovo-a6000	aarch64	2015	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y	Y	-	-
Lenovo A6010	lenovo-a6010	aarch64	2015	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	Y			Y	Y	Y	P	-
LG Optimus Vu	lg-p895	armv7	2012	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	Y						P	Y
Motorola Moto G4 Play	motorola-harpia	aarch64	2016	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	Y	N	Y	Y	Y	Y	P	
OnePlus 6	oneplus-enchilada	aarch64	2018	Y	Y	Y	Y	P	Y	Y	Y	Y	Y	Y	N	P	P	P	P	P	P
OnePlus 6T	oneplus-fajita	aarch64	2018	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	Y	N	P	Y	Y	P	P	P
PINE64 PinePhone	pine64-pinephone	aarch64	2020	Y	-	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	Y	Y	-
PINE64 PinePhone Pro	pine64-pinephonepro	aarch64	2021	Y	-	Y	Y	Y	Y	P	Y	Y	Y	Y	P	Y	Y	Y	Y	N	-
Purism Librem 5	purism-librem5	aarch64	2020	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	Y	Y	Y	-
Samsung Galaxy A3 (2015)	samsung-a3	aarch64	2014	Y	Y	Y	P	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y
Samsung Galaxy A5	samsung-a5	aarch64	2014	Y	Y	Y	P	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y
Samsung Galaxy E7	samsung-e7	armv7	2015	Y	Y	Y	P	Y	Y	Y	Y	P	Y	Y	N		Y	Y	Y	Y	Y
Samsung Galaxy Grand Max	samsung-grandmax	armv7	2015	Y	Y	Y	Y	Y	Y	Y	Y	P	Y	Y	N		Y	Y	Y	Y	-
Samsung Galaxy S III	samsung-m0	armv7	2012	P	Y	Y	Y	Y	Y	Y	Y	Y	P	P	P	N	N	N	N	Y	-
Samsung Galaxy S4 Mini Value Edition	samsung-serranove	armv7	2015	Y	Y	Y	Y	Y	Y	Y	P	-	Y	Y	N	Y	Y	Y	Y	-	-
SHIFT SHIFT6mq	shift-axolotl	aarch64	2020	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	N	Y	Y	Y	N	N
Wileyfox Swift	wileyfox-crackling	aarch64	2015	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	P	-
Xiaomi Mi 9T / Redmi K20	xiaomi-davinci	aarch64	2019	Y	Y	Y	Y	Y	Y	P	Y	Y	P	Y	P	P	Y	Y	Y	Y	P
Xiaomi Mi A1	xiaomi-tissot	aarch64	2017	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	P	P	Y	P	Y	-
Xiaomi Mi A2 Lite	xiaomi-daisy	aarch64	2018	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	P	P	Y	P	Y	-
Xiaomi Mi Note 2	xiaomi-scorpio	aarch64	2016	Y	Y	Y	Y	Y	P	P	Y	N	P	Y	P	N	N	P	N	Y	Y
Xiaomi POCO X3 NFC	xiaomi-surya	aarch64	2020	Y	Y	Y	Y	Y	Y	P	Y	Y	P	Y	N	N	Y	Y	Y	Y	Y
Xiaomi Pocophone F1 / POCO F1	xiaomi-beryllium	aarch64	2018	Y	Y	Y	Y	P	Y	P	Y	Y	Y	Y	P	P	P	P	P	N	-
Xiaomi Redmi 2	xiaomi-wt88047	aarch64	2015	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	-
Xiaomi Redmi 4 Prime	xiaomi-markw	aarch64	2016	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	Y	P	P	P	Y	Y	Y	-
Xiaomi Redmi 5 Plus	xiaomi-vince	aarch64	2017	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	Y	P	P	P	Y	P	Y	-
Xiaomi Redmi Note 4 / 4X	xiaomi-mido	aarch64	2017	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	P	P	Y	Y	Y	-
Xiaomi Redmi S2 / Redmi Y2	xiaomi-ysl	aarch64	2018	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	P	P	P	Y	Y	Y	-

## Kernel support for Mobile Linux: The missing 20%

- $\geq 80\%$  of functionality is working for lots of devices
- What's commonly missing?
  - Cameras, Battery fuel gauge driver, Phone calls / mobile data, A subsection of essential functionality
- Bringup is quite straightforward for recent devices
- Getting some functionality upstream is difficult
- Functionality & Reliability



## Cocoa / Cocoa Touch

UIKit

GameKit

MessageUI

MapKit

## Media

Core Image

Core Audio

OpenGL ES

Core Animation

AVFoundation

Core Text

Quartz

## Core Services

SQLite

Core Foundation

Core Location

CFNetwork

Core Motion

Foundation

Core Data

WebKit

## Core OS

Content Providers

Managers

Activity

Location

Package

Notification

View System

Resource

Telephony

Window

## Native C/C++ Libraries

Webkit

OpenMAX AL

Libc

Media Framework

OpenGL ES

...

## Android Runtime

Android Runtime (ART)

Core Libraries

# Architecture

## Hardware Abstraction Layer (HAL)

Audio

Bluetooth

Camera

Sensors

...

## Linux Kernel

Drivers

Audio

Binder (IPC)

Display

Keypad

Bluetooth

Camera

Shared Memory

USB

WiFi

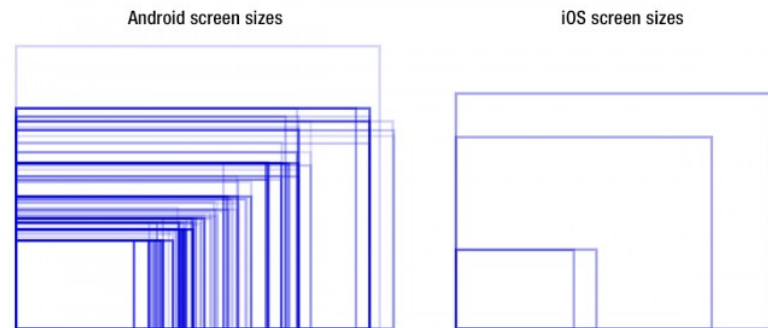
# Boot

- FSBL (hardware ROM)
- Bootloader
  - u-boot (blob, bootldr, redboot, able, etc.)
- Kernel
  - Haliu (libhybris)
- Device tree / EFI
- Initramfs
- Rootfs + Systemd (SYS V init)
- Bootstrapping
  - chicken or the egg problem
  - Limited resources
- Requirements
  - Keyboard vs. Volume keys vs Touch screen only
  - charging



# User space

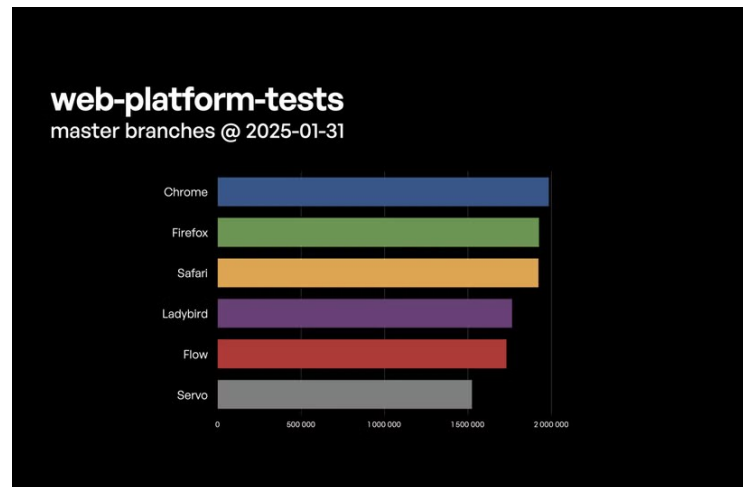
- GUI – ~~Framebuffer, XOrg~~, Wayland
  - On-screen keyboard (maliit, squakboard, ...)
  - Not rectangular screens (camera notch, circular screen - watches)
- Modem / Networking
  - oFono, Modem Manager, AT+?, QMI (Qualcomm modem iface), VoLTE
- Audio - PulseAudio profiles (/ ALSA / PipeWire)
- Applications
  - Native apps, Flatpak, Waydroid, Browser



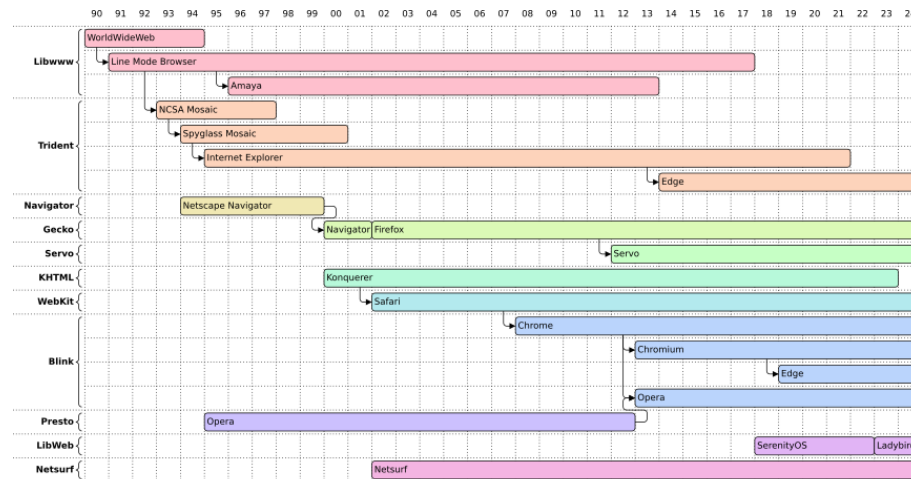
Source: <http://opensignal.com/reports/2014/android-fragmentation/>

# The last mile of a marathon is tough

- Browsers are hard
  - Embedded apps (electron)
  - Tons of APIs (bluetooth, serial, storage, camera, webgl, video)
- mobile-config-firefox



	Gecko	Webkit	Blink
Phosh	Firefox	Epiphany WebKitGTK	Chromium QtWebEngine
Plasma Mobile			Chromium QtWebEngine Angelfish, Maui-Fiery
Ubuntu Touch		Mimi WPE	Morph, Sapot QtWebEngine
Sailfish OS	Sailfish Browser Sailfish WebView		



# Android based OS Comparision and/or Waydroid

Based on

## Freedom

Free and open source (FOSS)?  
Deblobbed?

## Features

Network controls for apps  
Network-based location (without GNSS)  
System-wide connection/tracker blocking  
E2E-encrypted phone backups  
Notification forwarding from other user profiles  
Duress PIN (to wipe device)  
Android Auto compatible  
Google Play compatible

## Degoogling (connections to Google) colours

eSIM activation  
Provider for network-based location  
SUPL (for Assisted GNSS)  
PDS/XTRA ("Standard" depends on GPS chipset)  
Connectivity check/captive portal  
DNS connectivity check  
DNS server fallback  
Network time  
Hardware attestation provisioning  
DRM (Widevine) provisioning

## Google Play Services

Implementation  
Optional?  
Runs in standard app sandbox?  
Can be limited to user or work profile?  
Signature spoofing needed/allowed?  
Push notifications via Google FCM?  
Google Play Integrity?

## Privacy

Storage scopes  
Contact scopes  
Per-app sensor controls  
Per-connection DHCP state flushing  
MAC address randomization  
SUPL: IMSI or phone number sent?  
Qualcomm XTRA: user agent sent?  
Closed cross-profile package leaks?  
Closed device identifier leaks?  
Metadata stripping for screenshots  
EXIF metadata stripping for photos  
Location tagging for photos  
Tracking through Android Advertising ID?

## Security

Verified boot (if supported by device)?  
Hardware-based security verification  
System app downgrade protection  
Secure application spawning?

	GrapheneOS	CalyxOS	IodéOS	/e/	LineageOS	"Stock" Android
						
	AOSP	AOSP	LineageOS	LineageOS	AOSP	AOSP
Based on	Yes	Yes	Yes	Yes	Yes	No
Freedom	Yes, significantly	Yes, significantly	Yes, minimal	Yes, minimal	Yes, minimal	No
Deblobbed?	Yes, significantly	Yes, significantly	Yes, minimal	Yes, minimal	Yes, minimal	No
Network controls for apps	Direct and indirect access	Direct access only	Direct access only	Direct access only	Direct access only	No
Network-based location (without GNSS)	Emulated default, or Play Services	microG location	microG location	microG location	No	Play Services
System-wide connection/tracker blocking	Private DNS setting, or via VPN app	Private DNS setting, or via VPN app	iode-snort app, Private DNS, or VPN	Private DNS setting, or via VPN app	Private DNS setting, or via VPN app	Private DNS setting, or via VPN app
E2E-encrypted phone backups	Yes (Seedvault)	Yes (Seedvault)	Yes (Seedvault)	Yes (Seedvault)	Yes (Seedvault)	Yes, but requires Google login
Notification forwarding from other user profiles	Yes	No	No	No	No	No
Duress PIN (to wipe device)	Yes, <a href="#">see here</a>	No	No	No	No	No
Android Auto compatible	Yes (sandboxed), <a href="#">see here</a>	No	Yes, <a href="#">see here</a>	Yes, <a href="#">see here</a>	No	Yes
Google Play compatible	No	No	No	No	No	Yes
eSIM activation	Google eUICC (preinstalled)	Google eUICC (preinstalled)	Google eUICC (preinstalled)	Google eUICC (preinstalled)	Google eUICC (preinstalled)	Google eUICC (preinstalled)
Provider for network-based location	Emulated/default, or Google	microG location	microG location	microG location	n/a	Google
SUPL (for Assisted GNSS)	GrapheneOS default, Google or none	Google default, or none	Google default, or none	None default, or Google	Google default, or none	Google
PDS/XTRA ("Standard" depends on GPS chipset)	GrapheneOS default, Standard, or none	Standard (excl. Google) default, or none	Standard (excl. Google) default, or none	None default, or Standard	Standard default, or none	Standard
Connectivity check/captive portal	GrapheneOS default, Google, or none	Google (can be changed)	Kuketz.de (can be changed)	Murena.io (related to /e/) (can be changed)	Google (can be changed)	Google (can be changed)
DNS connectivity check	GrapheneOS default, or Google	Google	Google	Google	Google	Google
DNS server fallback	Cloudflare	Cloudflare	Quad9	Quad9	Google	Google
Network time	GrapheneOS default, or none	Google (can be changed) & carrier	NTP.org (can be changed) & carrier	NTP.org (can be changed) & carrier	Google (can be changed) & carrier	Google (can be changed) & carrier
Hardware attestation provisioning	GrapheneOS default, or Google	Google	Google	Google	Google	Google
DRM (Widevine) provisioning	GrapheneOS default, or Google	Google	Google	Google	Google	Google
Implementation	GmsCompat (sandboxed Google Play)	microG	microG	microG	None by default. It's possible to install microG manually (LineageOS <a href="#">supports signature spoofing for microG</a> since 2024). Alternatively, there are <a href="#">ROMs with microG preinstalled</a> or one can <a href="#">add Google apps</a> during the installation process, but this is not officially supported by LineageOS.	Google Play Services
Optional?	Yes (not preinstalled)	Yes (preinstalled but opt-out)	Yes (preinstalled but opt-out)	No (preinstalled without opt-out)	manually (LineageOS <a href="#">supports signature spoofing for microG</a> since 2024). Alternatively, there are <a href="#">ROMs with microG preinstalled</a> or one can <a href="#">add Google apps</a> during the installation process, but this is not officially supported by LineageOS.	No (preinstalled without opt-out)
Runs in standard app sandbox?	Yes	No	No	No	manually (LineageOS <a href="#">supports signature spoofing for microG</a> since 2024). Alternatively, there are <a href="#">ROMs with microG preinstalled</a> or one can <a href="#">add Google apps</a> during the installation process, but this is not officially supported by LineageOS.	No
Can be limited to user or work profile?	Yes	Yes	? (TBC)	? (TBC)	manually (LineageOS <a href="#">supports signature spoofing for microG</a> since 2024). Alternatively, there are <a href="#">ROMs with microG preinstalled</a> or one can <a href="#">add Google apps</a> during the installation process, but this is not officially supported by LineageOS.	No
Signature spoofing needed/allowed?	No	Only for Google signature	Only for Google signature	Only for Google signature	manually (LineageOS <a href="#">supports signature spoofing for microG</a> since 2024). Alternatively, there are <a href="#">ROMs with microG preinstalled</a> or one can <a href="#">add Google apps</a> during the installation process, but this is not officially supported by LineageOS.	No
Push notifications via Google FCM?	Yes	Optional	Optional	Optional	manually (LineageOS <a href="#">supports signature spoofing for microG</a> since 2024). Alternatively, there are <a href="#">ROMs with microG preinstalled</a> or one can <a href="#">add Google apps</a> during the installation process, but this is not officially supported by LineageOS.	Yes
Google Play Integrity?	Passes Basic Integrity only, <a href="#">see here</a>	Passes Basic Integrity only	No but basic integrity expected soon	No but basic integrity expected soon	manually (LineageOS <a href="#">supports signature spoofing for microG</a> since 2024). Alternatively, there are <a href="#">ROMs with microG preinstalled</a> or one can <a href="#">add Google apps</a> during the installation process, but this is not officially supported by LineageOS.	Yes
Storage scopes	Yes, <a href="#">see here</a>	No	No	No	No	No
Contact scopes	Yes, <a href="#">see here</a>	No	No	No	No	No
Per-app sensor controls	Yes, <a href="#">see here</a>	No	No	No	No	No
Per-connection DHCP state flushing	Yes	No	No	No	No	No
MAC address randomization	Per connection, <a href="#">see here</a>	Per network	Per network	Per network	Per network	Per network
SUPL: IMSI or phone number sent?	No	No	No	No	No	Yes
Qualcomm XTRA: user agent sent?	No	Partially (for Qualcomm chips)	Partially (for Qualcomm chips)	Partially (for Qualcomm chips)	Partially (for Qualcomm chips)	for Qualcomm GPS chips
Closed cross-profile package leaks?	Yes	No	No	No	No	No
Closed device identifier leaks?	Yes, <a href="#">see here</a>	No	No	No	No	No
Metadata stripping for screenshots	Yes, <a href="#">see here</a>	Yes, <a href="#">see here</a>	No	No	No	No
EXIF metadata stripping for photos	Yes, <a href="#">see here</a>	No	No	Available as option	No	No
Location tagging for photos	Opt-in	Opt-in, <a href="#">see here for more info</a>	Opt-in	Opt-in	Opt-in	Opt-out
Tracking through Android Advertising ID?	Not part of the system	Randomized ID	Randomized ID	Randomized ID	Not part of the system	Yes, but can be deleted in settings
Verified boot (if supported by device)?	Yes, incl. system app updates	Yes, but excl. system app updates	Yes, but excl. system app updates	w/ test keys; excl. system app updates	No	Yes, but excl. system app updates
Hardware-based security verification	Yes, <a href="#">see here</a>	No	No	No	No	Some devices, <a href="#">see here</a>
System app downgrade protection	For updates and boot, with fs-verity	For updates (incomplete)	For updates (incomplete)	For updates (incomplete)	For updates (incomplete)	For updates (incomplete)
Secure application spawning?	Yes (exec)	No	No	No	No	No

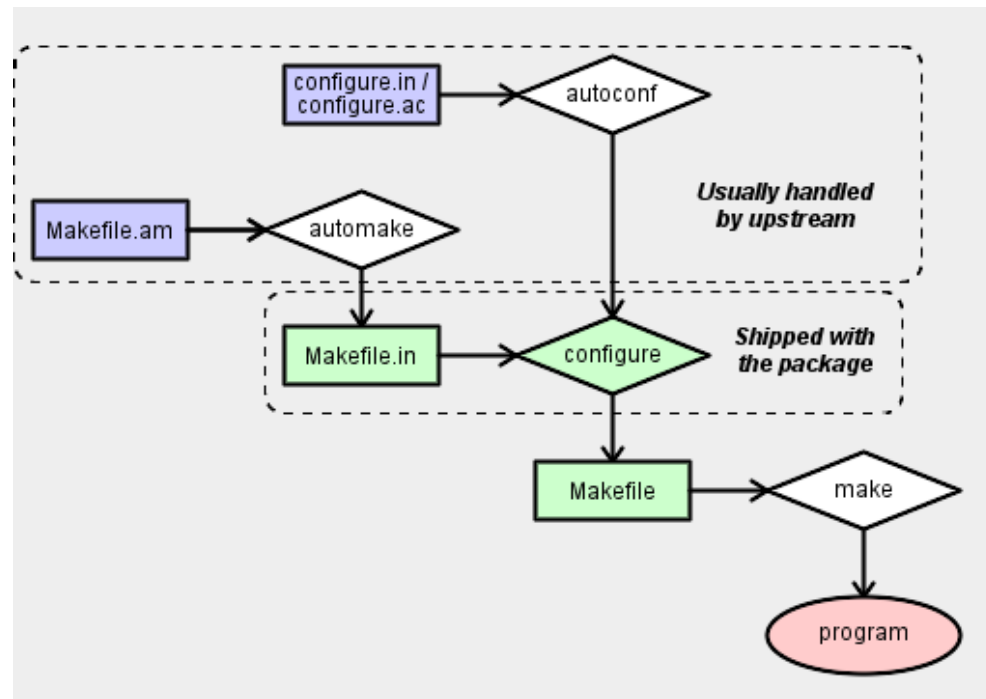
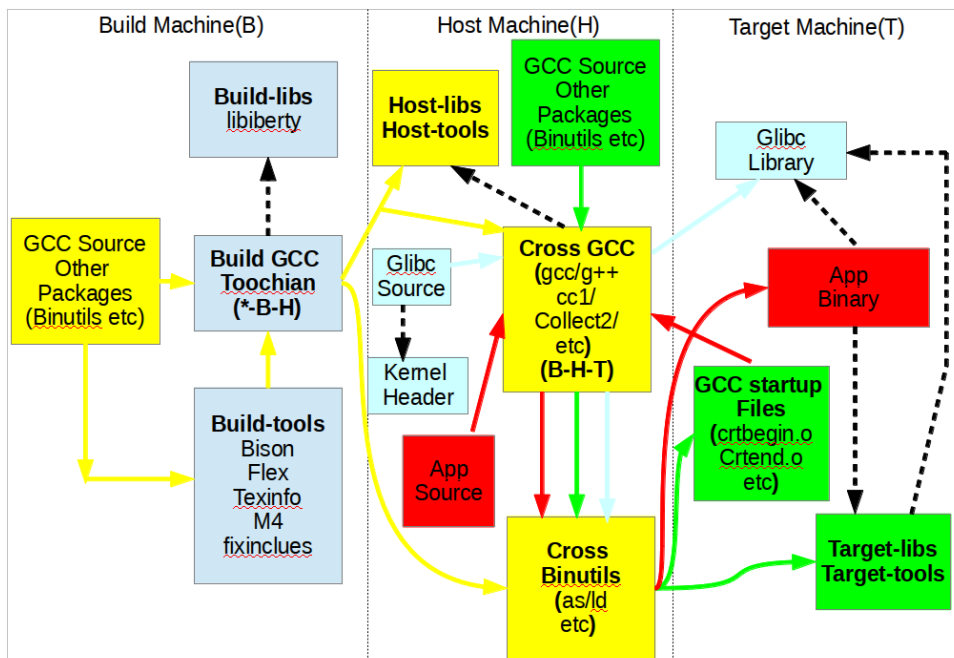




# Development

# Compilation

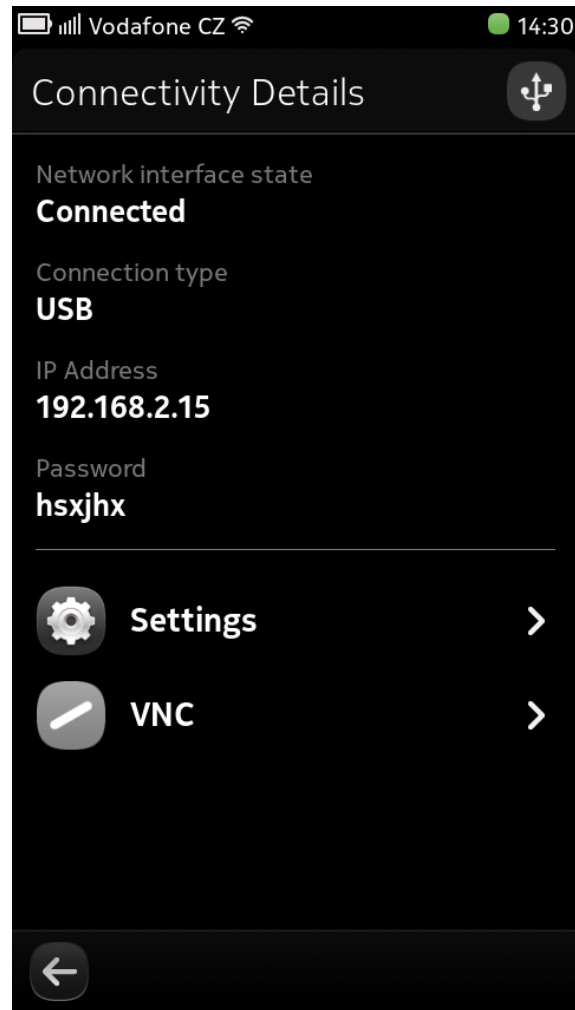
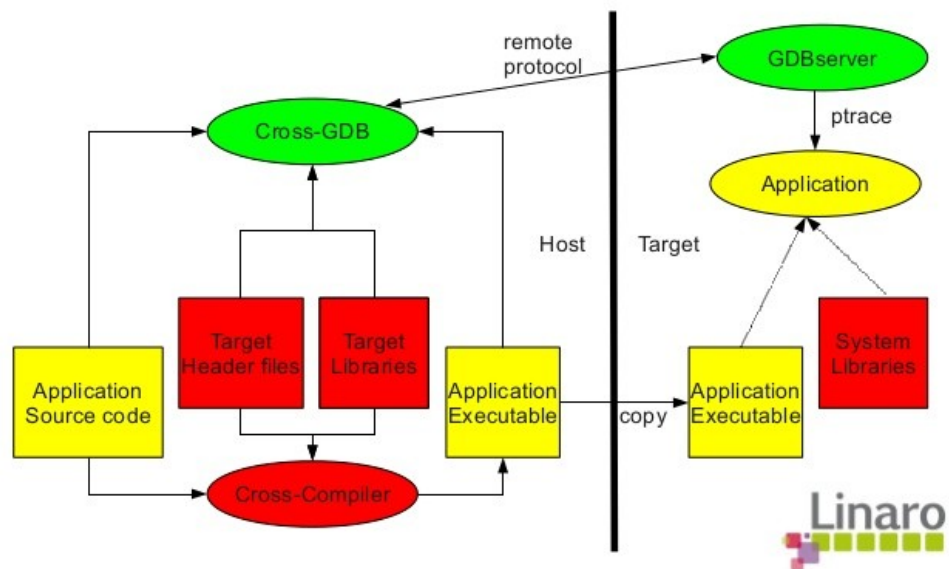
```
export CC=/usr/local/bin/arm-linux-gnueabi-gcc
export CFLAGS=-I /usr/local/arm_root/include
make
qmake myproject.pro -r -spec linux-g++-maemo
```



# Remote debugging

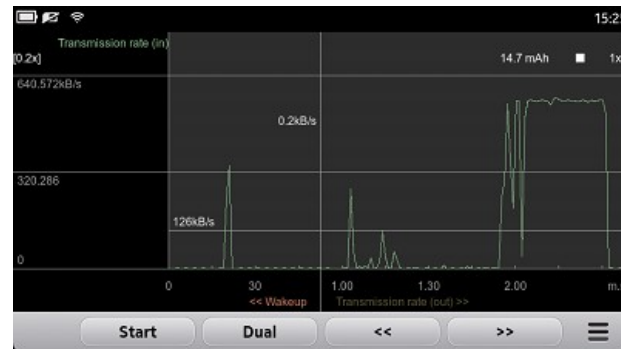


## Remote debugging



# Profiling

- Monitor
  - CPU load
  - Memory consumption
  - Network traffic  
(change of IM timeout added +1h)
  - Number of waking up and suspends (C-states)
  - Frequency of CPU
  - Interrupts (IRQs)  
(or NAPI)
- gproof, powertop, and much more  
(perf cheat sheet)
- [1] SD card performance



*Pro-tip: try to use “heartbeat” or Qt::VeryCoarseTimer to spare some CPU ticks.*

*Android AlarmManager.setInexactRepeating(..)*

## Demo: Clickable

- `sudo add-apt-repository ppa:bhdouglass/clickable`
- `apt install clickable`
- `clickable setup`
- `clickable create`
- `clickable build`
- `clickable desktop`
- `clickable build --arch arm64 --app --skip-review && clickable install --arch arm64 && clickable launch --arch arm64 && clickable logs --arch arm64`



Questions?