The GNSS Subsystem

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Introduction

- Global Navigation Satellite System (GNSS)
    - GPS (US)
    - GLONASS (Russia)
    - BeiDou (China)
    - Galileo (EU)
- Satellite-based radio navigation
    - Position, velocity and time (PVT)
- GNSS receivers currently managed in user space
- Serial device bus (serdev) allows for a higher-level abstraction
    - Power management
    - Device detection

Outline

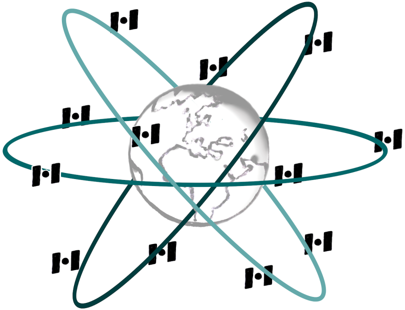
- Background and theory
- User interface
- Driver interface
- Currently supported devices
- Limitations
- Future work

GNSS history

- Ground-based radio navigation (1940s)
    - Gee, LORAN, Decca
- Satellite-based radio navigation
    - Transit (1960s)
    - GPS, GLONASS (1970s)
    - BeiDou (1990s)
    - Galileo (2000s)
- Politics
    - Military purposes
    - GPS Selective Availability (2000)
- Miniaturisation
    - First single-chip receiver (2004)
    - Smartphone with GPS (2007)
    - 5.8 billion GNSS devices in 2017 (forcasted to 8 billion in 2020)

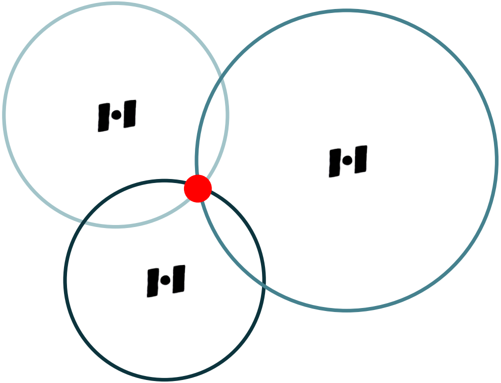
GNSS theory

- Satellites
  - 24 + 6 satellites in three orbital planes (Galileo example)
  - Atomic clock
- Radio signals
  - L band (1–2 GHz)
  - Timing signal
  - Navigation data (ephemeris, status, ...)
- Receivers
  - Track satellites and estimate pseudo ranges
  - Position, velocity and time (PVT)



GNSS receivers

- Antenna, front-end, baseband signal processing, application processing
- Acquisition and tracking
- PVT solution (2D, 3D)
- Time to first fix (TTFF)
    - Cold, warm and hot start
- I/O interfaces (UART, ...)
    - Reports (out)
    - Control (in)
- Power supplies and enable signals



Receiver I/O interfaces

- UART
- I2C
- SPI
- Remote processor messaging (rpmsg)
- MMIO
- USB
- SDIO
- ...

Receiver protocols

- Periodic reports + control
  - Position, velocity and time
  - Satellites in view
- NMEA 0183
  - National Marine Electronics Association (1980s)
  - De-facto standard
  - Subset with vendor extensions
  - Proprietary
  - Much have been reverse-engineered
- Vendor protocols
  - Garmin, SiRF Binary, UBX, ...
  - Proprietary
  - NMEA and vendor mode (runtime configurable)

NMEA 0183

```
$GPGGA,092750.000,5321.6802,N,00630.3372,W,1,8,1.03,\
        61.7,M,55.2,M,,*76
```

- Checksummed (printable) ASCII sentences
    - Time, position and fix-related data
    - Position
    - Velocity
    - Satellites in view
    - Time and date
- Incomplete PVT reports
- Underspecified report cycles
- No standard control commands (vendor extensions)
    - Port settings
    - Message rates

GNSS and Linux

- Handled in user space
    - gpsd
    - Android location services
- UART-interface only (TTY)
    - Custom drivers and hacks for non-UART
- Device description in user space
    - Device and protocol detection hacks
- Power management
    - Modem control signals (DTR)
    - GPIOs (gpiolib)

GTA04 GPS power management

- GTA04, OpenMoko
- Wi2Wi SiRFstar-based GPS receiver
  - `onoff` input, but no `wakeup` output signal
  - Monitor data channel to determine power state
- Various proposals over the years
  - Neil Brown, Nikolaus Schaller and others
- Serial device bus (serdev)
  - Finally possible to implement in kernel
  - Specific wi2wi serdev driver with custom TTY interface
- Need a GNSS-receiver framework

Problem statement

- I/O interface abstraction
- Device description and discovery (e.g. Device tree or ACPI)
- Power management
  - Regulators, GPIOs, clocks...
  - Data stream (GTA04)
- Vendor protocols...

Design decision

- Keep everything in user space?
  - User-space drivers
  - Some resources not available (e.g. regulators, clocks)
  - Device descriptions in user space
  - No I/O-interface abstraction
  - System-suspend coordination

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- Handle everything in kernel?
  - Proprietary protocols
    - Legal issues
    - Non-reverse engineered
  - String parsing
  - Device-dependent features and quirks
  - Hard to generalise protocols
  - Would require new user-space services
  - Floating-point math?

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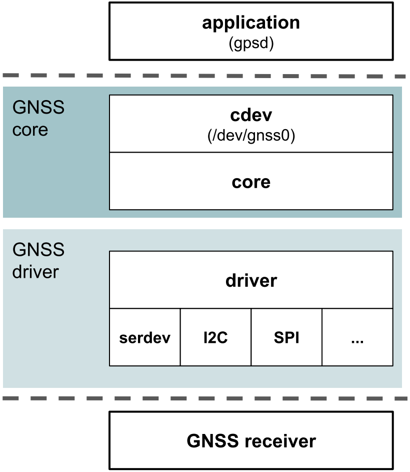
  - Floating-point math?
- Keep protocol handling in user space

The GNSS subsystem

- Raw character-device interface
    - Protocols handled in user space
- I/O-interface abstraction
- Device detection and description
- Power management
- Compatible with current user space
- Can be extended with high-level interface later
- Merged in 4.19



User interface

- GNSS class device
  - `/sys/class/gnss/gnss0`
- `type` sysfs attribute and `GNSS_TYPE` uevent variable
  - "NMEA"
  - "SiRF"
  - "UBX"
- Character device
  - `/dev/gnss0`
  - Pollable read, 4k buffer
  - Synchronous write

Device-tree bindings

- Child node of I/O interface node
- Generic properties
    - compatible (required)
- Additional resources

```
&uart1 {
    gnss {
        compatible = "wi2wi,w2sg0084i";

        vcc-supply = <&gnss_reg>;
        sirf,onoff-gpios = <&gpio0 16 GPIO_ACTIVE_HIGH>;
        sirf,wakeup-gpios = <&gpio0 17 GPIO_ACTIVE_HIGH>;
    };
};
```

Driver interface

- Allocation and registration
- Insertion of raw protocol data
- Callbacks for opening, closing and writing

Driver-interface functions

```
struct gnss_device;

struct gnss_device *gnss_allocate_device(...);
void gnss_put_device(...);

int gnss_register_device(...);
void gnss_deregister_device(...);

void gnss_set_drvdata(...);
void *gnss_get_drvdata(...);

int gnss_insert_raw(...);
```

- `gnss_insert_raw()` serialised by caller, any context

Driver-interface callbacks

```
struct gnss_operations {
        int (*open)(struct gnss_device *);
        void (*close)(struct gnss_device *);
        int (*write_raw)(struct gnss_device *,
                         const unsigned char *, size_t);
};
```

- `open()` called on first open
- `close()` called on final close (or disconnect)
- `write_raw()`
    - Synchronous, may sleep

Power management

- Handled on interface level (e.g. serdev device)
- Runtime power management
    - Open serial port and enable receiver using RPM on `open()`
    - Allows user space to set always-on (`power/control`)
- System suspend
    - Enable low-power mode or power off

Serial-library functions

```
struct gnss_serial;

struct gnss_serial *gnss_serial_allocate(...);
void gnss_serial_free(...);

int gnss_serial_register(...)
void gnss_serial_deregister(...);

void *gnss_serial_get_drvdata(...);
```

- Generic serial GNSS-driver implementation
- Callbacks for power management

Serial-library callbacks

```
enum gnss_serial_pm_state {
        GNSS_SERIAL_OFF,
        GNSS_SERIAL_ACTIVE,
        GNSS_SERIAL_STANDBY,
};

struct gnss_serial_ops {
        int (*set_power)(struct gnss_serial *gserial,
                        enum gnss_serial_pm_state state);
};
```

- `ACTIVE` - open or runtime active
- `STANDBY` - closed or system suspended
- `OFF` - driver unbound

Merged drivers

- SiRFstar receivers (`sirf`)
  - Main supply
  - `onoff` input
  - `wakeup` output
  - Not using serial library (`wakeup` NC)
  - Not-connected `wakeup` not yet supported (e.g. GTA04)
- u-blox receivers (`ubx`)
  - Main and backup supplies
  - Serial library

Limitations

- Line-speed handling
    - Coordinate protocol and interface control
    - New GNSS ioctl()?
    - Handle in kernel?

Hotplugging

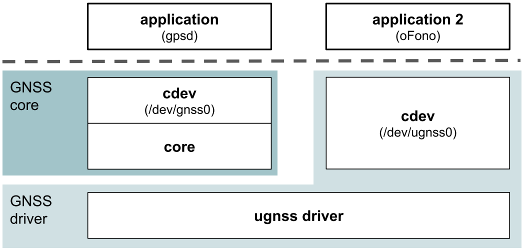
- USB-serial-connected receivers
- Unique `idVendor` and `idProduct`?
  - Kernel descriptions
  - User-space descriptions
- GNSS core supports hotplugging
- But serdev does not (yet)

Modems

- GNSS receiver integrated with modem
  - Assisted GPS (A-GPS)
  - Reduce time to first fix (e.g. almanac and time from network)
- Modems managed in user space
  - oFono telephony stack
- Kernel interfaces
  - TTY (cdev)
  - Phonet (socket)
  - CAIF (socket)
  - CDC WDM (cdev)
- Example
  - Control commands on one port (e.g. power management)
  - GNSS reports on another (e.g. NMEA 0183)

ugnss

- User-space GNSS drivers
- Feed raw data to GNSS core
- Accessible through common interface
- Needed while modems are managed in user space
- Can also be used for testing



Future work

- Pulse per second (PPS)
- Low-noise amplifiers (LNA)
- ugnss
- Line-speed handling
- High-level interface?

Further reading

- *GNSS Market Report Issue 5*, European GNSS Agency
    - `https://www.gsa.europa.eu/system/files/reports/gnss_mr_2017.pdf`
- *Navipedia*, European Space Agency
    - `https://gssc.esa.int/navipedia/index.php/Main_Page`
- *Towards A Better GPS Protocol*, Eric S. Raymond
    - `http://www.catb.org/gpsd/replacing-nmea.html`
- *Why GPSes suck, and what to do about it*, Eric S. Raymond
    - `http://esr.ibiblio.org/?p=801`

Thanks!

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