Addressing the hard problems of automotive Linux: networking and IPC

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Outline

• Status of Linux in automotive
• GENIVI and AF_BUS IPC
• V2V and V2I networking
• New stakeholders for Linux
• Summary
Housekeeping: IVI Jargon

- “OEM”: a car manufacturer
- “Tier 1”: a vendor who sells directly to OEMs
- “Tier 2”: a vendor to Tier 1s, who bundle components
- “ECU”: electronic control unit, 32- or 16-bit MCU running an RTOS
- “AUTOSAR”: ECU protocol incl. design methodology
- “ADAS”: advanced driver assistance system
Linux won:
- on servers and on handsets.

Linux lost:
- on desktops.

Linux could lose in automotive:
- QNX and Windows have the largest automotive base.
- QNX has fast IPC and works well on smaller MCUs.
- Most car CPUs run proprietary RTOSes.
## Current Public Status of Automotive Linux

<table>
<thead>
<tr>
<th>OEM</th>
<th>Confirmed Operating system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiat-Chrysler Blue&amp;Me (500, Delta), Kia Uvo</td>
<td>Microsoft Windows Embedded Automotive</td>
</tr>
<tr>
<td>Ford (all?)</td>
<td>MyTouch/ Sync-Microsoft (OpenXC-Android)</td>
</tr>
<tr>
<td>General Motors/Cadillac User Experience</td>
<td>Linux</td>
</tr>
<tr>
<td>Geely (China); Hawtai (China)</td>
<td>Linux: Moblin (MeeGo-Tizen precursor)</td>
</tr>
<tr>
<td>Renault R-Link</td>
<td>Android</td>
</tr>
<tr>
<td>Honda (Accord, Odyssey, Pilot), Audi (A8L, Q5, A6), BMW (7-series and M models), Chrysler, Daewoo, GM (OnStar), Hyundai, Land Rover, Porsche, Saab (9-3), Renault (SM7), Mercedes (S- and C-class)</td>
<td>QNX</td>
</tr>
</tbody>
</table>

**Linux Foundation** members: Toyota, Pelagicore, Symbio, Tieto

**Automotive Grade Linux**: JLR, Nissan, Toyota, Tier N's

**GENIVI Alliance**: 160+ members including 11 “OEMs”
GENIVI Alliance

• **Goals:**
  – reduce lock-in by Tier 1 vendors.
  – reduce cost and TTM of new models.

• **Methods:**
  – Promote code reuse via standard interfaces.
  – Grow the size of contributor community.
  – Focus on middleware: not a distro.

• *Projects with released code:* Audio Manager, IVI Layer Management, Diagnostic Log and Trace, AF_BUS D-Bus Optimization, LXCBENCH; more on the way.

• Mailing lists and #genivi on FreeNode.
TRUE:

What's the next big platform for Linux?

by Glyn Moody

Glyn Moody wonders whether the car – a currently undeveloped yet important platform with great potential – can provide the inspiration for the next generation of Linux coders.

FALSE:

Since then, Genivi has moved even closer to Linux: for example, the Linux Foundation now hosts key Genivi projects. However, Genivi is only about IVI – "in-vehicle infotainment". That's an important part of a vehicle's operations, but doesn't involve the fundamentals – things like the engine or braking systems – that are arguably closer to its heart. That's what made this announcement last year noteworthy:

http://www.h-online.com/open/features/What-s-the-next-big-platform-for-Linux-1794404.html
The strange case of AF_BUS
Mixture of time-critical and best-effort networks
Anyone reminded of this Babel?
Diverse IPC mechanisms, Legacy Protocols

- TCP/IP?
- UDP/IP?
- RemoteProc?
- D-Bus?
- FlexRay
- EthernetAVB
- EtherCAT
- J1939

or maybe

- FPD-Link
- I2C
- Sensor
- ECU
- MCU
- SPI
- PWM
- Actuator
- Backup video or "Mirror" video
- Driver webcam

rear-seat display (LVDS)
Challenges to Standards for Linux IPC

- “IP is the narrow waist of the Internet” BUT

- TCP/UDP headers are too large for AUTOSAR packets.
  - 6LoWPAN header compression offers a solution?

- Event-driven and timer-based traffic coexist on same network.
  - Will asynchronous networking provide QoS?

- AudioManager, LayerManager, AF_BUS define policies to enable whole-system-level interrupts and priorities.
CAN-Ethernet Gateway Demo


- ARM Cortex A8
- Linux Ångström v 2.6.28
- Stack “SocketCAN”
- Can and Ethernet on chip

Two independent threads. Uses socket paradigm as an abstraction to transparently copy messages on different physical layers.
GENIVI meets kernel: AF_BUS

- Problem: D-Bus scales poorly, is resource-intensive and slow.
- Recent history of contention around IPC: binder in 2009
- AF_BUS is created by Collabora with GENIVI-funding.
- Implements a new socket interface based on AF_UNIX but with multicast capability.
- Rejected from mainline with rationale that IP sockets can provide needed performance.
  - Real-time IPC guarantees possible with IP?
- AF_BUS subsequently merged in LTSI kernel 3.4.21.
Feb 2013: **Gnome Hackfest**

- New *in-kernel* D-Bus-based IPC is broached.
  - Will support Binder userspace API as well as D-Bus.
  - And others (0MQ, RabbitMQ, etc.)?
- **Endorsed** by D-Bus (Pennington) and *kernel* (GKH) contributors.
- *Victory* for GENIVI: in-kernel D-Bus optimization is coming!
- Not viewed that way by everyone . . .
- brcmsmac vs. b43 (Broadcom) redux?
Automotive networking background – extravehicular
Vehicles are a “network of networks”
802.11p & 1609: DSRC, WAVE and WSMP

- 802.11p has **dedicated spectrum** at 5.9 GHz.
- Unlike other 802.11, **no BSS**.
- **New protocols**, e.g. DNS Geocasting
- **New use cases**, e.g. mobile routers
- **VIN == MAC?** or is VIN private?
- Jouni Malinen, 2012 Linux Wireless Summit, "Not yet implemented."

802.11p V2X routers

Linux-based

StreetWAVE™ Roadside Unit: Supports V2X Safety and Mobility applications using DSRC, 3G

BSD-based?

Commsignia
Collision avoidance is primary motivation.
USDoT had RFC on PKE for V2X in 2012.
How to issue revocable keys w/o trackability?
Automotive Grade Linux

- Initiated September 2012.
- An installable distro like Android (unlike GENIVI).
- Development in open (unlike Android or GENIVI).
- No CLA, but no GPLv3 (like Android and GENIVI).
- Mailing lists available but very quiet.
- So far, based entirely on Tizen.
Open source has new allies
Reflashing the ECUs: uprev.com

<table>
<thead>
<tr>
<th>Flash Status</th>
<th>Instructions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Osiris Cable</td>
<td>Verify that ALL electrical loads are shut off (seat heaters, climate control fans, headlights, etc...)</td>
</tr>
<tr>
<td>ECU Part Number</td>
<td>23710 - CF44A</td>
</tr>
<tr>
<td>Detected ECU Voltage</td>
<td>15.04V</td>
</tr>
<tr>
<td>Security Status</td>
<td>OK</td>
</tr>
<tr>
<td>Main CPU</td>
<td>Gen2 CPU</td>
</tr>
</tbody>
</table>

**INSTRUCTIONS**

1. Connect the cable to a free USB port, and to the vehicle diagnostics port.
2. Use the [Load] button and locate the ROM that you'd like to flash.
3. If the file is loaded correctly and the ECU is ready, the ECU status should be "OK".
4. Click the [Flash ECU] button and follow any on screen instructions.
5. After the flash has completed you will need to shut the vehicle off and then turn it back on when prompted.
6. After "Reflash Complete" flashes for a few seconds, the prompt should return to "ECU Ready!"
Conclusions

• Hardest problem of automotive Linux is *cultural*.

• The Linux community and kernel devs and “Tier n” software creators need to work together.
  - Make accommodation for mutual benefit, as with Android.

• Kernel quality *standards must be maintained*

  **BUT**

  OEMs need to ship reliable, safe cars every year.

• Drivers, transit planners, insurance companies, home mechanics are stakeholders, too.
Related automotive presentation

*John Mehaffey*, Mentor Graphics,
*Security Best Practices for Embedded Systems*
Friday at 3:15 in Cyril Magnin

Special thanks

*Massimiliano Ruggeri* of Imamoter, *John Kenney* of Toyota,
*Ravi Puvvala* of Savari Networks, *Christie Dudley* of Santa Clara University Law School, *Mentor Embedded and GENIVI colleagues*
Resources

- GENIVI open-source projects, mailing lists, #genivi IRC
- Automotive Grade Linux
- ITSSv6, CALM, Imamoter, ETSI, ISO C-ITS
- SAE, IEEE, AUTOSAR, ISO, IETF, W3C standards
- IETF-ITS mailing list; Telematics News and Telematics Update, Wired Autopia
- Reverse-engineering legions: scantool.net, mp3car.com, diyefi.org, Team Wikispeed
- LWN and H-Online (as always!)
Early backup video and v4l2

• NHTSA proposed a requirement for annotated, composited backup video 2s after boot.
  – Announced for 12/2012: nothing yet.
• Likely solution for fast-boot: a dedicated camera ECU or CPU.
  – What network architecture optimizes BW, cost and reliability?
• Jaguar Land-Rover: 8 cameras in new ADAS systems.
• Cameras will also be used for gesture recognition.
  – Now possible with specialized IP cores (Samplify et al.).
Cars talk on the Internet of Things

**MY ENERGI LIFESTYLE**

More than ever, cars are sharing the same energy source as the home. The average American home uses over 11,000 kWh of electricity every year. But we can do something about it.

Recent technology advancements and utility trends have enabled a typical American middle-class family to significantly reduce their electricity bills and CO₂ footprint by integrating a plug-in vehicle, energy-efficient appliances and a renewable energy source.

Behind all these products is the power cloud computing that takes advantage of lower off-peak electric rates.
## High-Bandwidth feasible buses overview

<table>
<thead>
<tr>
<th></th>
<th>IEEE 802.3</th>
<th>Ethernet Field busses</th>
<th>CAN-FD</th>
<th>Flexray</th>
<th>MOST</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Openness</strong></td>
<td>Open standard, high availability of PHYs and MACs</td>
<td>Usually open standard, some have custom PHYs and MACs</td>
<td>Under ISO standardization ISO-11898-2/6 transceivers</td>
<td>Under ISO standardization (or flexray.com) Expensive controllers</td>
<td>Closed Standard. Expensive Fiber wiring</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td>1000/100 Mbit</td>
<td>100 Mbit (not every fieldbus Gigabit ready)</td>
<td>Up to 8x CAN datarate→2Mbit for ISOBUS (theoretical)</td>
<td>Up to 10 Mbit</td>
<td>Up to 138Mbit (MOST 150)</td>
</tr>
<tr>
<td><strong>Hotplug capability</strong></td>
<td>YES</td>
<td>Depends on the field bus</td>
<td>YES</td>
<td>NO (attempts were made to enable)</td>
<td>YES</td>
</tr>
<tr>
<td><strong>Topology</strong></td>
<td>Star, Logical Bus, daisy chain, ...</td>
<td>Ring, Daisy chain, Star in some topologies</td>
<td>Physical Bus</td>
<td>Star</td>
<td>Ring or doubled ring, star feasible</td>
</tr>
<tr>
<td><strong>Safety certified</strong></td>
<td>NO (OpenSafety)</td>
<td>Many fieldbuses have IEC-61508 SIL3 certified Layer</td>
<td>??</td>
<td>NO</td>
<td>??</td>
</tr>
</tbody>
</table>

*From “SAE J 1939 Over Real Time Ethernet: The Future of Heavy Duty Vehicle Networks,” Ruggeri et al., Imamoter*
Another view of automotive networks
**SPI used as communication stack**

- **Impact:** SPI interface module needed

**Note:** two or more MCUs

*Courtesy of AUTOSAR Consortium*
Phasing in autonomous operation

- *Prediction*: in U.S., incentives to buy cars with V2X radios.
  - Usage-based insurance motivates driver acceptance.
- *Prediction*: congestion pricing everywhere all the time.
  - Drivers get discounts for travelling off-peak.
- *Prediction*: stop signs and traffic lights disappear.
- Optimization at the whole transport-system level is enabled by vehicles talking on the Internet of Things.
  - Pollution, energy usage and travel times can be jointly managed
CAN-Ethernet Gateway Demo