NuttX at Fitbit

fitbit | Andrei Voinescu

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Introduction to NuttX
What is NuttX?

• An RTOS for embedded devices
  • Standards compliance (POSIX)
  • Small footprint
  • “Tiny Linux”
• Developed by Gregory Nutt
NuttX core principles

- Strict standards compliance - POSIX
- Modular and Scalable Architecture
- Open and Unencumbered License
- Consistent Coding Style
Available anywhere

- AVR, Z80
- ARM - ARM7/9/11, Cortex A8/9, M0/3/4, R4
- Xtensa
- MIPS
- Risc-V
- x86/x86_64
Where is NuttX used?

• Digital audio recorders
• Bluetooth headphones
• Drones & Robots
• IoT devices
• Fiscal printers
• ... and now fitness trackers
What does an OS like NuttX offer?
NuttX - General Abstractions

• Unix-like user environment
  • libc + POSIX interfaces
• Realtime characteristics
NuttX - Processing Abstractions

- Code runs in tasks or processes
- Code can be static or dynamically loaded
- Priorities, Preemption, Realtime
- pthreads
- Synchronization (Mutexes, semaphores)
- IPC (Message queues, signals)
NuttX - Storage Abstractions

• Everything is a file descriptor
• Pseudo Root Filesystem
• Mountable filesystems
• Wear-leveling Flash filesystems
• FAT, NFS, TMPFS, ROMFS
NuttX - I/O Abstractions

• Shell, pseudoterminals/PTYs
• Block and character device drivers
• Peripheral drivers (I2C, SPI, PWM, CAN)
• Socket API
• Full TCP/IP stack, 6lowpan
• Wireless MAC layers (802.11, 802.15.4)
• USB Host/Device - CDC, HID, Mass Storage
NuttX - Memory Abstractions

- Hardware-dependent kernel separation
  - Flat
  - Protected
  - Kernel
- Various stack & heap possibilities
NuttX - Others

• Power Management
• Window Manager
• Audio subsystem
• Crypto drivers
• Interpreters
• libc
Trackers and Fitbit
• US company - San Francisco
• Wearables - activity trackers, smartwatches
• Steps, heart rate, sleep & more!
In just over a decade...

...we’ve inspired millions of people to live healthier, more active lives.

*As of Q3 2019

- 28M+ active users*
- 100M+ devices sold*
- 202T steps counted
- 517B minutes of exercise
- 228B hours of heart rate
- 10.5B nights of sleep
Fitbit is #1 in Trackers in EMEA*

Charge #1 tracker franchise in EMEA**

Fitbit 12 years leading the Tracker category**

*IDC Q2 2019 Quarterly Wearable Device Tracker, Wristband and Modular, Based on Sales Value  **Validation pending via
Current Product Lineup
TRACKERS with NuttX

Charge 3
October 2018

Inspire
Inspire HR
March 2019

Ace 2
June 2019

Charge 4
April 2020
The best selling Fitbit Charge family now with built-in GPS

**Inspiration to get outdoors with built-in GPS**
Real-time pace & distance, 7 GPS workout modes, Workout Intensity Maps (in app)

**Move better with Active Zone Minutes**
Updated HR zones, on-wrist zone haptics, new AZM app experience

**Wake more refreshed with enhanced sleep tools**
Sleep Score, Smart Wake, Sleep Mode

**Convenient tools to keep you focused**
Spotify control, Fitbit Pay, agenda, weather, timer

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**Charge 4**
2 styles-
BLACK; ROSEWOOD

**Charge 4**
Special Edition
GRANITE REFLECTIVE WOVEN BAND / BLACK TRACKER
Special Edition Includes:
Extra black classic band
# Features Overview

Compare the enhanced features that give you more ways to live your best life.

<table>
<thead>
<tr>
<th>Classic Features</th>
<th>What's New</th>
</tr>
</thead>
<tbody>
<tr>
<td>![Heart] 24/7 Heart Rate</td>
<td>![Question Mark] Build-in GPS</td>
</tr>
<tr>
<td>![Moon] Light, deep &amp; REM sleep tracking</td>
<td>![Notepad] Active Zone Minutes</td>
</tr>
<tr>
<td>![Message] Call, text and app notifications*</td>
<td>![Heart] Workout intensity map</td>
</tr>
<tr>
<td>![Battery] Up to 7 days battery**</td>
<td>![Music] Spotify App and on-wrist control</td>
</tr>
<tr>
<td>![Run] Tracks all day activity</td>
<td>![Run] New exercise modes for kayaking, skiing and more</td>
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<tr>
<td>![Sync] Syncs wirelessly</td>
<td>![Swim] Fitbit Pay</td>
</tr>
<tr>
<td>![Reminders] Reminders to move</td>
<td>![Settings] Do not disturb and sleep modes to mute smartphone notification</td>
</tr>
<tr>
<td>![Apps] Convenient apps like weather and timer</td>
<td></td>
</tr>
</tbody>
</table>

*When the phone is nearby  
**Up to 5 hours with GPS, varies with use and other factors
Integrating NuttX guidelines

• Use POSIX interfaces everywhere
• Maintain NuttX guiding design principles
• Maintain coding style throughout OS code
Extra OS features

- more IPC - pubsub, key-value store
- Initd - Runlevel management, task management
- Eventd - Event-based worker thread
Fitbit-specific Additions

- Sensor records & algorithms
- Transport layer to Fitbit Cloud
- Over-The-Air firmware update
- Fitbit UI
- Specific Drivers
Tracker OS overview

User modules
- Initd
- Eventd
- Fitbit Sensors & Algorithms
- Fitbit UI
- Fitbit Transport Layer Stack

NuttX
- Altimeter upper half
- Accelerometer upper half
- Common sensor upper half
- Framebuffer
- Vibe motor driver
- Button driver
- Socket API
- VFS
- IPC
- ROMFS
- SmartFS

SoC BSP
- I2C support
- SPI support
- BLE stack
- QSPI/QPI support

Hardware
- Sensor HW
- Display
- Haptics
- Button
- BLE transceiver
- External Flash
People
Team

• Varied during development
• Spread across geographies (mostly US and Romania)
• Currently:
  • OS team - Bucharest
  • Product teams - San Diego
  • Other subsystem teams across all Fitbit R&D offices
THANK YOU