NuttX at Fitbit

fitbit. | Andrei Voinescu

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

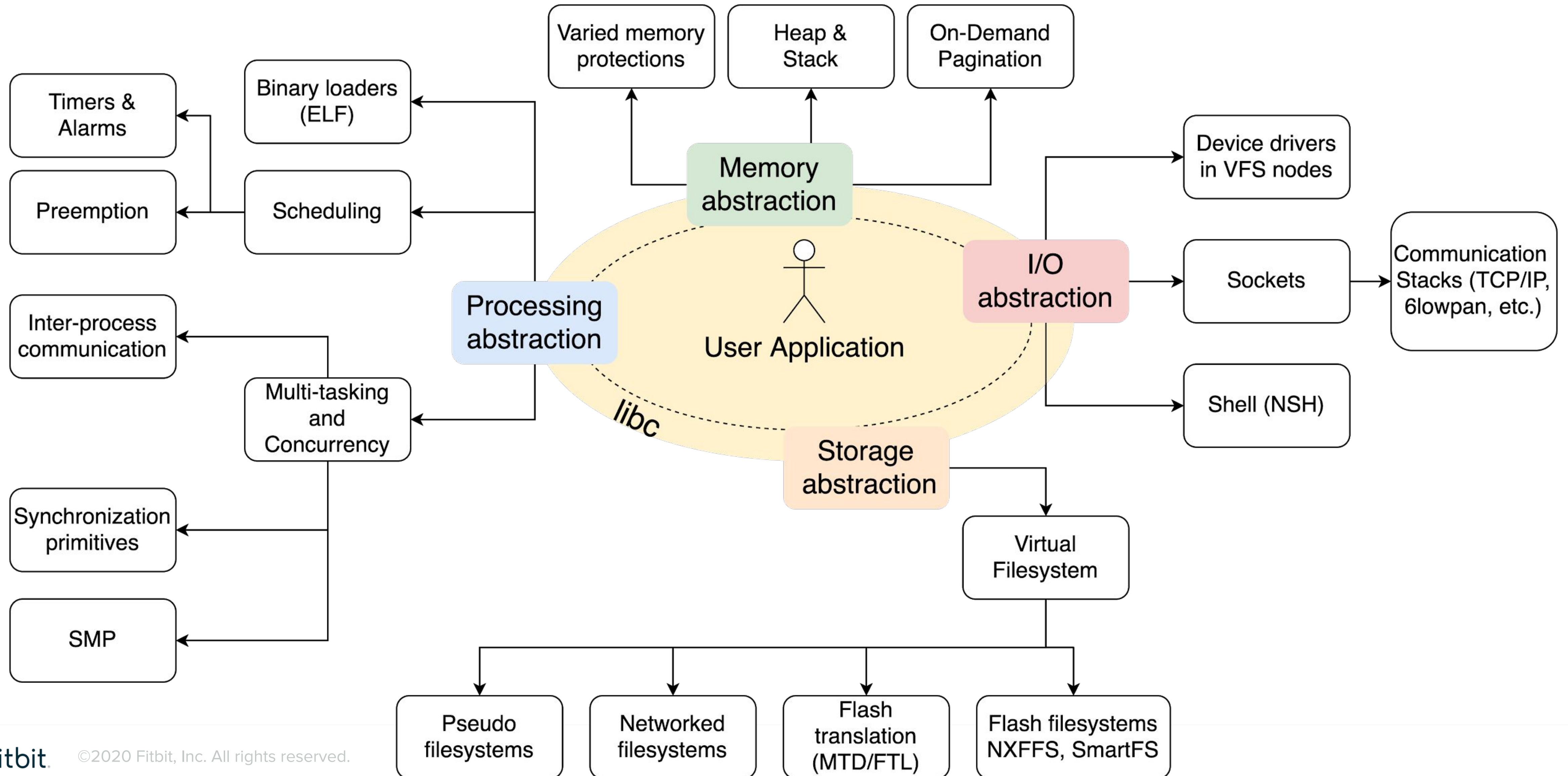- Open and Unencumbered License

- 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?

Timers & Alarms

Binary loaders (ELF)

Varied memory protections

Heap & Stack

On-Demand Pagination

Preemption

Scheduling

Memory abstraction

Device drivers in VFS nodes

Processing abstraction

I/O abstraction

Sockets

Communication Stacks (TCP/IP, 6lowpan, etc.)

Inter-process communication

User Application

Multi-tasking and Concurrency

libc

Shell (NSH)

Synchronization primitives

Storage abstraction

Virtual Filesystem

SMP

Pseudo filesystems

Networked filesystems

Flash translation (MTD/FTL)

Flash filesystems NXFFS, SmartFS

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.

28M+
active users*

100M+
devices sold*

202T
steps counted

517B
minutes of exercise

228B
hours of heart rate

10.5B
nights of sleep

*As of Q3 2019

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
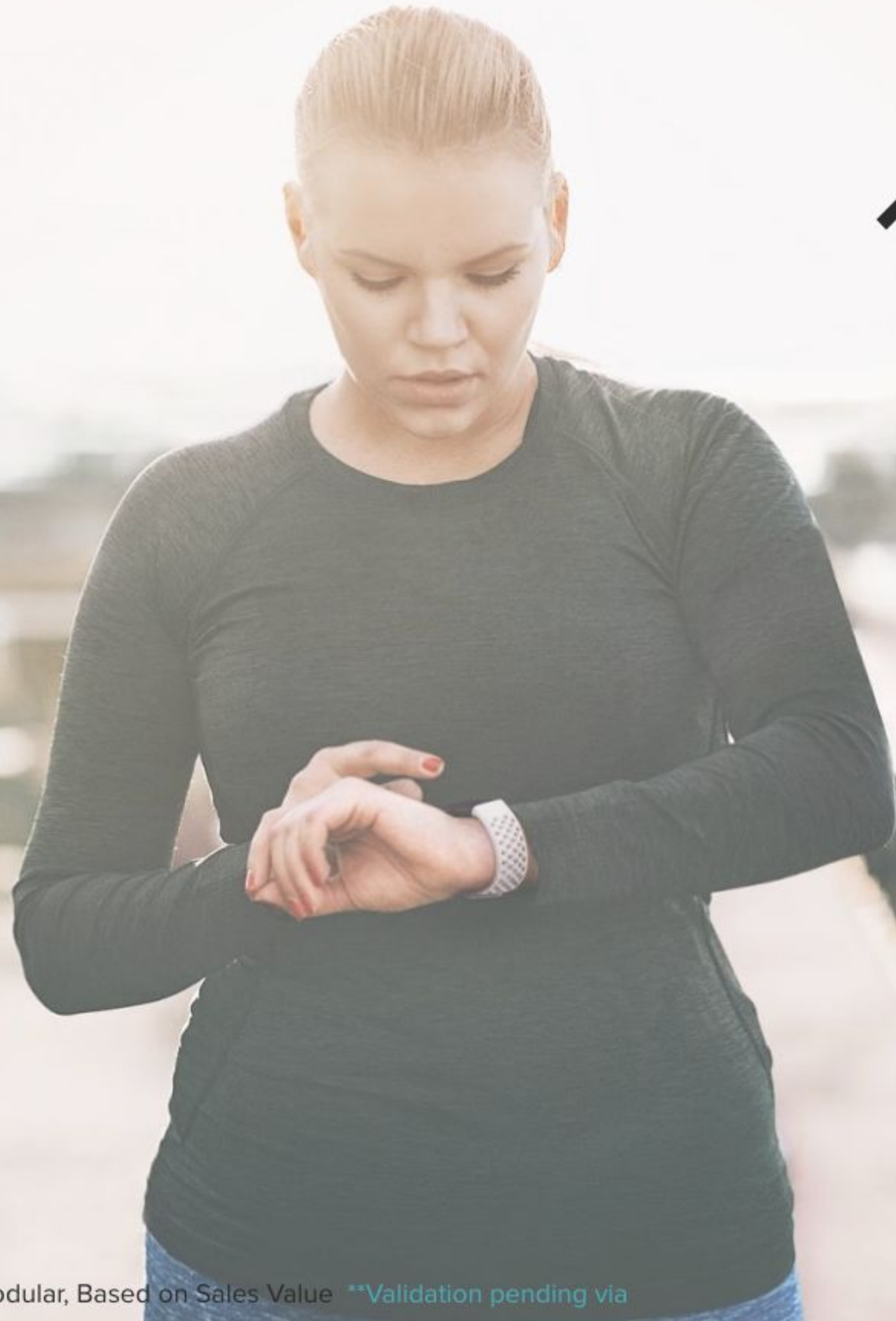
Current Product Lineup

TRACKERS with NuttX

Charge 3
October 2018

Inspire
Inspire HR
March 2019

Ace 2
June 2019

Charge 4
April 2020

fitbit charge 4

Charge 4
2 styles-
BLACK;
ROSEWOOD

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

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

Features **Overview**

![fitbit charge 4 logo]

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

Classic Features	What's New
24/7 Heart Rate	Build-in GPS
Light, deep & REM sleep tracking	Active Zone Minutes
Call, text and app notifications*	Workout intensity map
Up to 7 days battery**	Spotify App and on-wrist control
Tracks all day activity	New exercise modes for kayaking, skiing and more
Syncs wirelessly	Fitbit Pay
Reminders to move	Do not disturb and sleep modes to mute smartphone notification
Convenient apps like weather and timer	

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

Architecture

Integrating NuttX guidelines

- Use POSIX interfaces everywhere

- Maintain NuttX guiding design principles

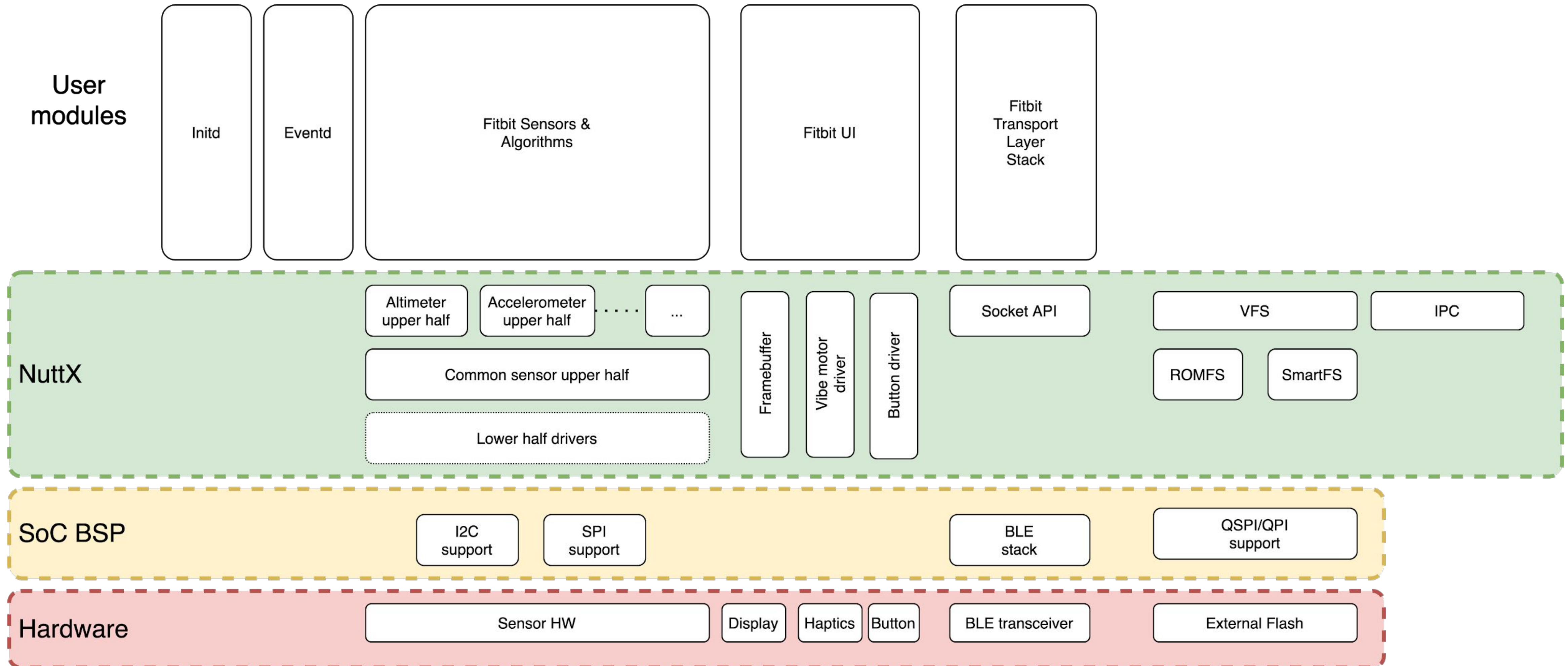- Maintain coding style throughout OS code

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
- Lower half drivers
- 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