



Leveraging IoT Biometrics and Zephyr™ RTOS for Neonatal Nursing in Uganda

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Agenda

- Problem statement
- Introduction to Neopenda
- Prototypes
- Selection criteria
- Software development
- Test results
- Android application
- Timeline
- Issues
- Conclusion

A Global Challenge: Ending Preventable Newborn Deaths



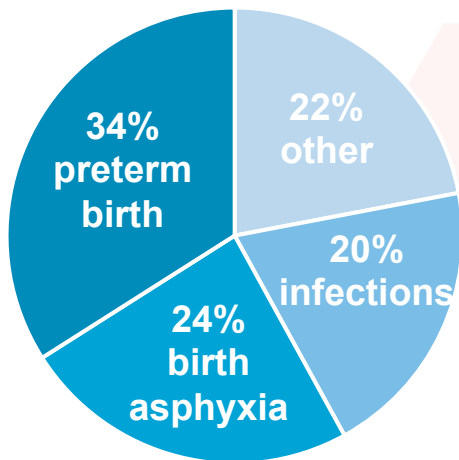
Every year in the developing world:

- 46 million newborns need special care from complications at birth
- 3 million newborns die
- 80% are from causes that are considered preventable and treatable by the WHO

Special Care Baby Unit at Mulago National Referral Hospital, Kampala, Uganda

Why Are Newborns Dying?

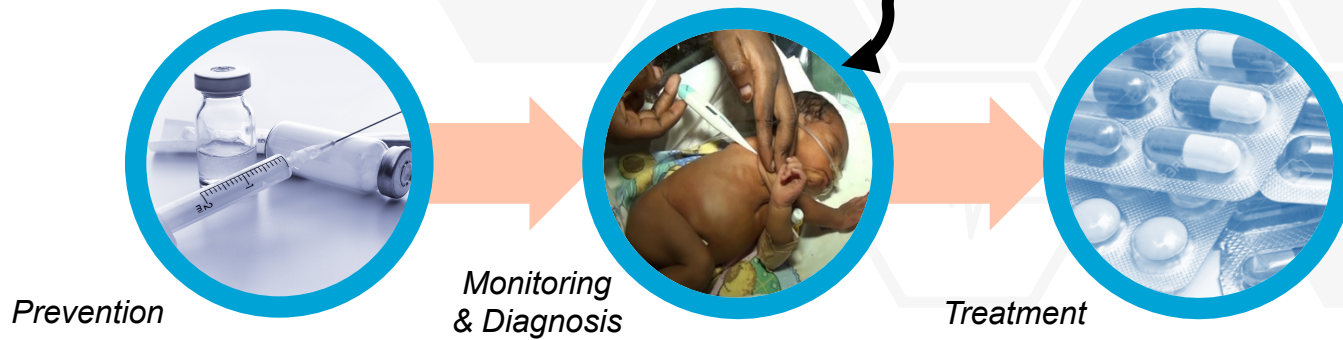
3 primary causes: all addressable with proper resources



- A major challenge area is providing quality care in resource-constrained hospital settings
- Key problem we are seeking to address: Hospitals in low resource settings severely lack staff and equipment, and are overburdened with patients

Newborn Mortality Is a Solvable Problem

- U.N. Sustainable Development Goal, target 3.1: By 2030, end preventable deaths of newborns and children under 5 years of age
- IoT for good: new cost and power friendly technologies offer benefits as easy to implement, scalable point-of-care solutions
- Where can technology make a difference?



What Is Neopenda?

- **Our mission:** To engineer innovative healthcare solutions that give newborns in low-resource settings the healthy start they deserve
- About me: Teresa Cauvel, MS in Biomedical Engineering from Columbia University. Co-founder and CTO.
- History:
 - Started project in a graduate course at Columbia University in early 2015
 - Formed the company August 2015 and went on first trip to Uganda
 - Participated in accelerator program Relevant Health 2015-2016
 - Now based in Chicago, IL
- Our partners include:



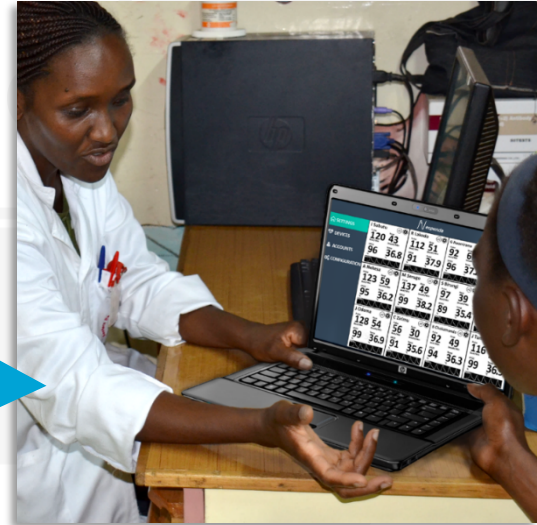
**Vodafone
Americas
Foundation**



At our partner hospital in Kampala,
August 2016

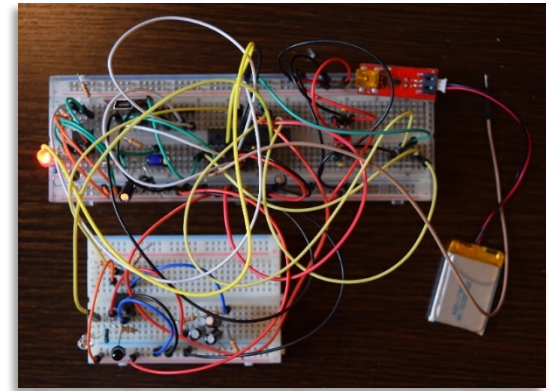
Our Product Vision

- A wearable vital signs monitor that measures heart rate, respiratory rate, blood oxygen saturation, and temperature
- Wireless communication to tablet, where health workers can view the status of every newborn in the room and be alerted in real-time of newborns in distress
- **Key constraints:**
 - Wireless
 - Low-power
 - Affordability
 - Ruggedness
 - Scalability

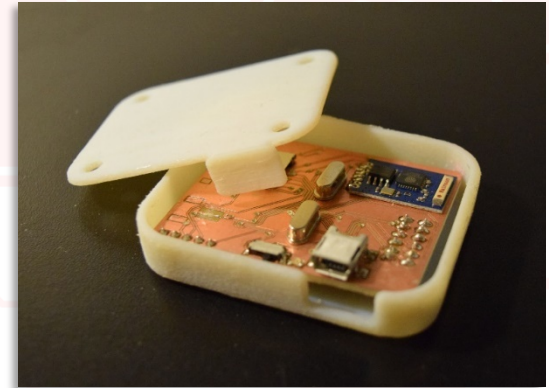


Early Prototyping

- Built with Arduino HW: first with Arduino Uno, then cut down to ATmega328 8-bit microcontroller
- Default Arduino SW
- Pulse oximetry + temperature sensors
- Used Wi-Fi because familiarity, versatility
- Sending data to a Windows PC
- **Transition needs:** BLE, size, non-PC clients



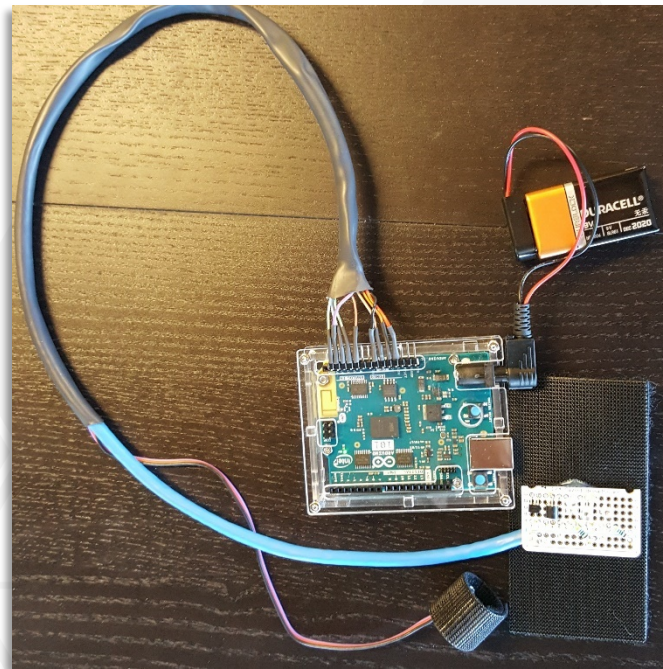
Early breadboarded system



One of first PCBs – 52x42mm

Getting Closer to a Deployable Product

- Arduino 101 with Intel® Curie™: low power solution designed for wearable devices
- Zephyr™ Kernel: small, scalable open source RTOS
- Sensors: Pulse Sensor, LilyPad temperature sensor, dual-LED optical sensor for pulse oximetry
 - Off-the-shelf to reduce risk; leverage expertise from Arduino community during prototype phase



Why Curie™ and Zephyr™?

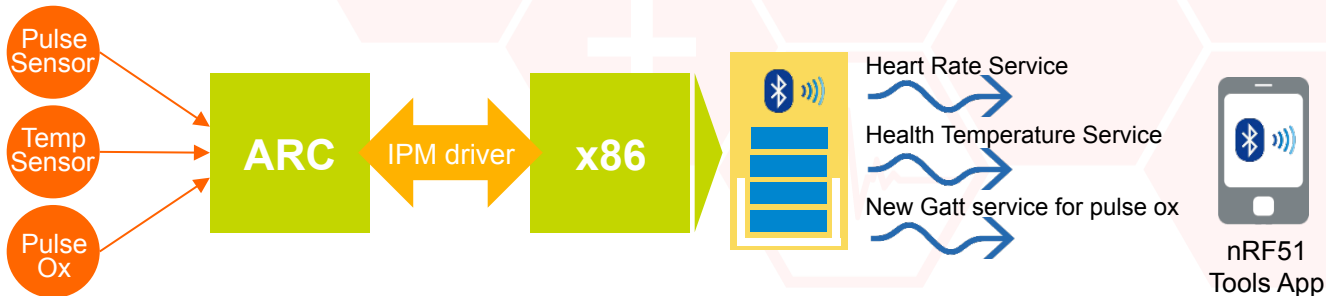
- Intel® Curie™ Module
 - Low cost, low power module with 12-bit A/D converters for accurate DSP measurement
 - Built-in Bluetooth LE radio
 - Built-in accelerometers and gyroscope sensors and pattern matching engine for further development
 - Size
- Zephyr™ Kernel
 - Supports ARC core (DSP subsystem) and x86 host chip concurrently
 - Support multi fibers & interrupts for complex sensors manipulation and communication
 - x86 chip has more RAM than others to support complex BLE applications
 - Rich support for drivers (ADC, GPIO, I2C, SPI, UART, BLE) and sensors, as well as sample codes
 - Reliable SDK with cross tool chain

Software Development with Zephyr™

- Zephyr™ SDK provides tool chains to compile for the DSP subsystem (ARC processor) and the host processor (X86)
 - Quick installation of compilers and tools chains.
 - GDB debugger working with both the DSP subsystem and the host processor. Eclipse IDE running with gdb for debugging.
- Many of sample codes for using BLE
 - Used `peripheral_hr` sample code as the starting point to get the heartrate measurement working with BLE.

Measuring the Four Vital Signs

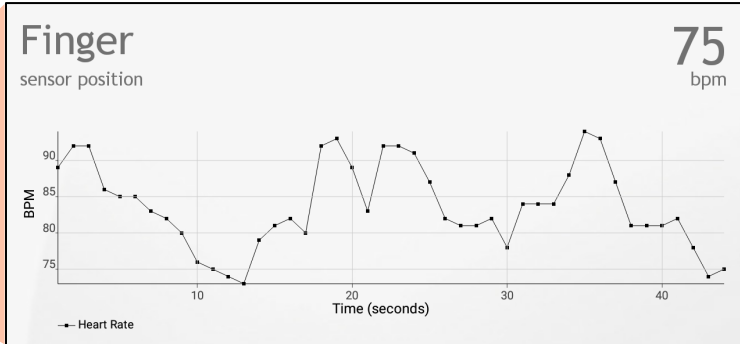
- Pulse rate and respiratory rate: Both calculated from A/D measurement using Pulse Sensor
 - ARC core sensor subsystem measures analog input using ADC driver
- Temperature: Measurement with LilyPad's MCP9700 sensor
 - Adjustments to ARC system to support separate tasks
- Pulse oximeter: Red and Infra-Red LEDs, TSL235 Light-to-Frequency converter
 - Multiplexed between the two LEDs to calculate absorption ratio
 - Used GPIO driver and its callback API to calculate the frequency
- Data flow:



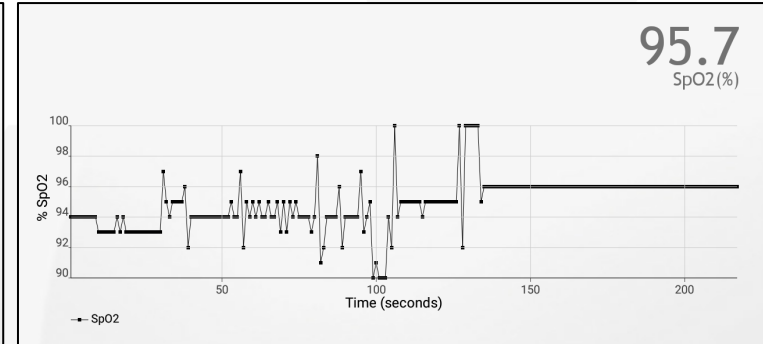
Test Results



Pulse rate



Blood oxygen saturation



Measurement	Preliminary Results
Pulse Rate	Identical readings to commercial pulse oximeter
Respiratory Rate	Derived from heart rate measurement, has a consistent 20-30% offset
Temperature	Variance of plus or minus 2 degrees C compared to commercial thermometer
Blood Oxygen Sat	Resolution same as commercial pulse oximeter, but tracks less accurately below 95%

Android Application



Timeline

Task	Approximate Effort
Ramp up on Zephyr™	1 week
Pulse rate measurement on Zephyr™	1 week
Respiratory rate measurement on Zephyr™	½ week
Temperature measurement on Zephyr™	1 week
Pulse oximeter hardware and measurement on Zephyr™	1 ½ weeks
Communicate and display measurements on Android application	2 ½ weeks

Issues

- Overestimation of arterial oxygen saturation in subjects with dark skin
- Cerebral pulse-ox sensors may induce more variation under hypoxic conditions
- Complex sensor and data manipulation
- BLE stability and connection control
- Power consumption: extending battery life

Conclusion

- We're looking forward to deployment of the completed solution
- We have partnered with the Uganda Paediatrics Association and St. Francis Nsambya Hospital for planning and executing pilot studies in 2017
- We plan to demonstrate feasibility and impact in Uganda, then expand to other low-resource countries in East Africa and around the world
- Please come talk to me if you have personal contacts with newborn health initiatives or neonatal units in developing countries
- Please come talk to me if you're working on health care solutions that use clever elements





Neopenda

Thank You

