Poster Abstract: Automating Decontamination of N95 Masks for Frontline Workers in COVID-19 Pandemic

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ABSTRACT

In response to the N95 mask shortage caused by the COVID-19 pandemic, the US CDC has recognized moist-heat as one of the most effective and accessible methods for decontaminating N95 masks for reuse. However, it is challenging to reliably deploy this technique in healthcare settings due to a lack of specialized equipment capable of ensuring proper decontamination conditions. To this end, we developed a wireless sensor platform for moist-heat decontamination process verification, capable of monitoring hundreds of masks simultaneously in commercially available heating systems. Our easy-to-use, low-power, low-cost, scalable platform can be broadly deployed to protect front-line healthcare workers by lowering their risk of infection from reused N95 masks.

CCS CONCEPTS

• **Computer systems organization → Embedded systems**.

KEYWORDS

N95 Masks Decontamination, Wireless Sensor, COVID-19

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1 BACKGROUND & MOTIVATION

The COVID-19 pandemic is causing global shortages of Personal Protective Equipment (PPE). Single-use N95 respirators in particular have seen persistent and prolonged supply shortages [3, 5]. As a result, healthcare workers have been forced to reuse N95 masks while treating sick patients, increasing the risk of infection.

Several N95 mask decontamination strategies such as Hydrogen Peroxide Vapor (HPV), autoclave treatment, microwave, gamma and UV-C irradiation have been proposed [7] but all require expensive specialized equipment. Other chemical decontamination processes such as Ethylene Oxide and bleach-based methods pose a risk of chemical exposure and potential harm to the wearer caused by toxic residuals [4]. Heating-based decontamination has been recognized as one of the most effective and easy-to-deploy decontamination methods [2]. Previous studies [1, 6] have shown how N95 masks held in a convective heating system within certain temperatures (70–85°C) and humidity (> 50%) for at least 30 minutes ensure a >3-log bioburden reduction for SARS-CoV-2 and similar coronaviruses in a lab setting while maintaining the masks filtration efficiency for 3–5 reuse cycles.

Due to the widespread availability of convective heating systems such as commercial ovens, moist-heat decontamination can be widely deployed in hospitals and under-resourced healthcare facilities. However, existing commercial equipment suffers from non-uniform heat and humidity distribution, making implementations with off-the-shelf equipment unreliable [6]. To overcome these challenges, we designed and built a mask decontamination platform composed of multiple wireless sensor nodes that monitors the decontamination process of each mask. Each fully assembled sensor node costs less than $40 in a batch of 1000, provides more than 1000 hours of battery life, and provides a drop-in solution for monitoring decontamination in under-resourced healthcare facilities facing N95 mask shortages.

2 SYSTEM DESIGN

During moist-heat decontamination, temperature and relative humidity need to be constantly monitored and verified. As shown in Fig. 1 (a), each N95 mask is placed in an individual container with one sensor node to ensure that local environmental conditions for virus inactivation have been met, and to avoid cross-contamination between masks [6, 8].

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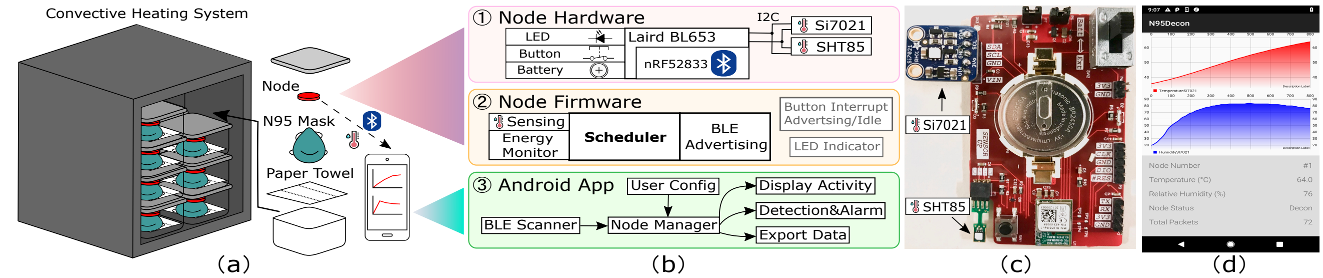

Figure 1: (a) Overview of the moist-heat decontamination process with our platform. (b) Architecture of the wireless sensor node's hardware, firmware, and Android App. (c) Wireless sensor node. (d) Monitoring App, single node display.

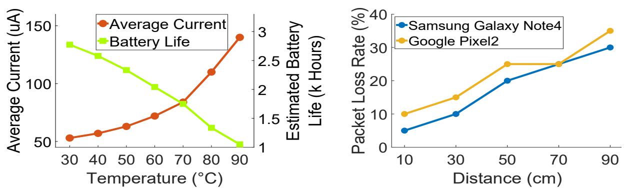

Figure 2: (Left) Average current consumption and estimated battery life under different temperatures. (Right) BLE packet loss rates at increasing distances.

2.1 System Architecture

At a high level, the platform's architecture (Fig. 1 (b)) consists of BLE sensor nodes that communicate with an Android application. The nodes periodically broadcast temperature and humidity data from each container via Bluetooth Low Energy advertisement. Non-connectable BLE advertising is chosen to minimize the nodes' power consumption, to increase the number of nodes the smartphone application can handle, and to quickly bind nodes to the application. Each sensor node consists of a Laird653 high-temperature-resistant wireless module powered by a lithium poly-carbon-monofluoride coin cell battery (Panasonic BR2450A, 550mAh), which is also rated for high temperatures. We include sockets for two temperature and humidity sensors (Silicon Labs' Si7021 and Sensirion SHT85) to facilitate replacement and maintenance. The Android application can collect, plot, and export temperature and humidity data from each sensor node. It also supports setting decontamination ranges for temperature and relative humidity, as well as automatic detection and notification of range violations. Each fully assembled sensor node costs $40 in a batch of 1000, providing a cost effective solution to decontamination.

3 EVALUATION

We used an EC12 Temperature Chamber (Sun Electronic Systems) as a convective heating system, and placed each N95 mask in a Pyrex glass food storage container with a sensor node (Fig. 1 (a)). A paper towel wetted with 500 μL of water generated the required humidity level in the container[6]. The app was tested on two phone models, a Samsung Galaxy Note4 (Android 6.0.1) and a Google Pixel2 (Android 9). Sensor readings were transmitted every 10s.

Results. Fig. 2 (Left) shows the node's current consumption and the estimated battery life under different operating temperatures with a 70% fudge factor applied to the battery capacity. Based on these results, we predict our node can successfully monitor continuously for over 1000 hours at high temperatures. Fig. 2 (Right) shows the BLE packet loss rate at different distances between the chamber and the smartphones. Considering the slow change rates of temperature and humidity in the containers [6, 8], the measured packet loss rate at 10s advertising interval is adequate for robust close-distance monitoring.

4 CONCLUSION AND FUTURE WORK

Our platform can provide reliable monitoring of N95 mask moist-heat decontamination processes and be used by under-resourced healthcare facilities respond to the N95 mask shortage. Future work will include developing standard operating protocols in cooperation with healthcare providers and equipping each sensor node with an energy harvesting system to eliminate the battery. Another future step is quantifying potential drifts due to prolonged exposure to high humidity level and temperature during decontamination.

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