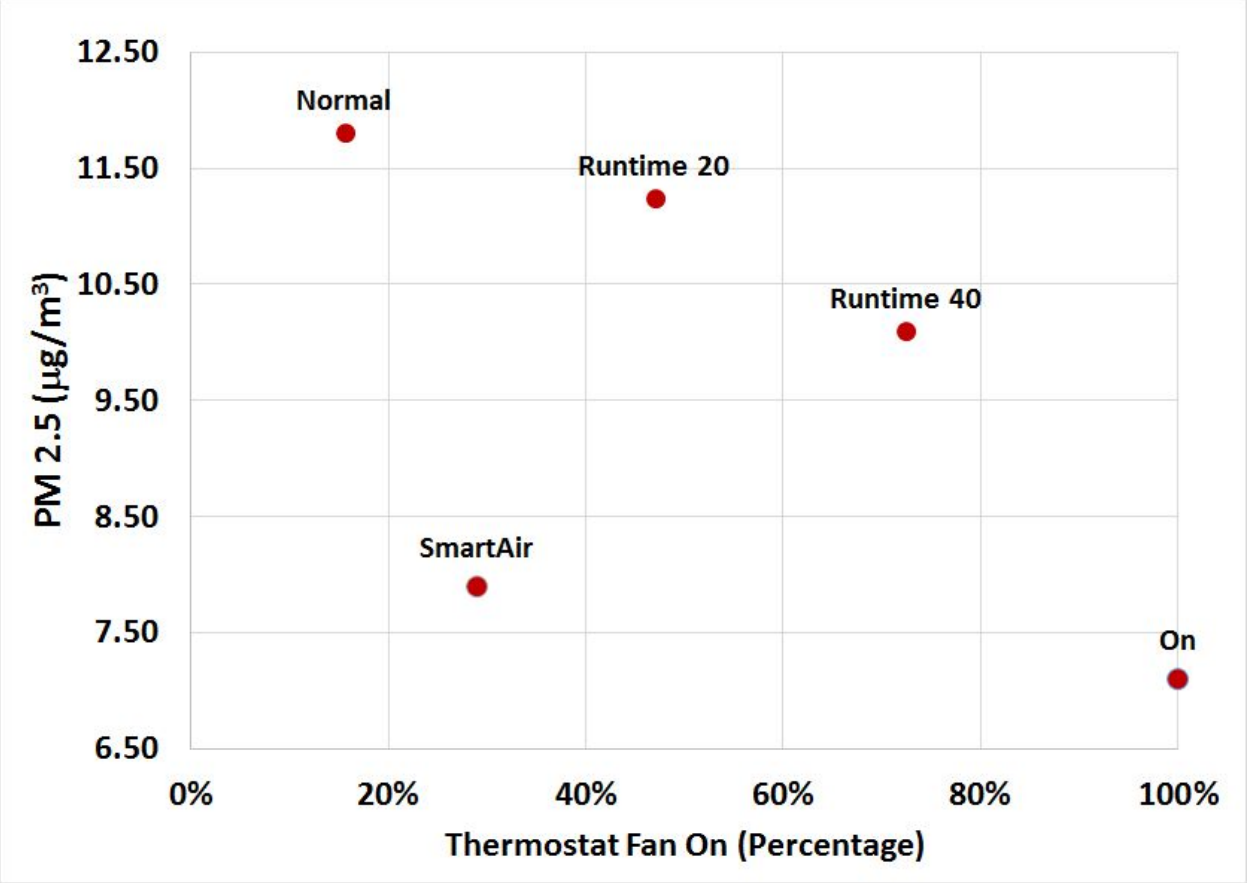
Abstract Title: IoT Performance Testing of SmartAir
Coauthors: Philip Lundrigan, Neal Patwari, Kathy Sward



Research says people spend approximately two-thirds of their day indoors and exposure to irritants such as allergens and small airborne particles can trigger asthma exacerbations. The CDC reported in 2014 that 17.7 million adults and 6.3 million children have asthma in the United States. Advances in embedded systems and the internet-of-things (IoT) have made it possible to continuously monitor indoor activities such as air quality and other in-home environmental exposures for use by home occupants and by researchers studying the relationship between exposure and health. Using an air purifier or furnace fan can filter the particulate matter, however, these devices consume significant energy.

We designed and built an air quality automation system called SmartAir that uses measurements from an airborne particulate matter sensor to control a home's furnace fan, pulling air through a filter to reduce the air pollutant concentration and consume less energy in the home. SmartAir's secure cloud server also allows epidemiologists and exposure scientists to collect real-time indoor air quality data, integrate with the automation services that control the

furnace fan at a household to reduce PM pollution, and run scientific experiments via randomized controlled trials (RCT). We deployed SmartAir in four homes for 350 days in which each day is a randomized experiment. The results demonstrate that SmartAir achieves air quality approximately as good as when the fan is always on (average PM2.5 of 6.13 $\mu g/m^3$ SmartAir vs. 5.71 $\mu g/m^3$ always on) while using 58% less energy. SmartAir also finds statistically significant lowering of PM2.5 for SmartAir vs. normal furnace fan operation.

This RCT-enabled SmartAir system can be extended to introduce a generalized system architecture called Thing-Enabled Self-Science (TESS), that automates the running and evaluation of RCTs on IoT-based automation systems. TESS can be easily programmed to connect various sensors and actuators. It also supports a repeated measurement randomized controlled trial of an IoT sensor/actuator system automatically. The randomization and control performed by TESS is designed to reduce bias and avoid the influence of confounding variables, and thus make a conclusion that is scientifically valid.