Poster Abstract: Zonal Air Handling in Commercial Buildings

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ABSTRACT

Commercial buildings and multi-unit residential buildings provide a setting for prolonged human-to-human contacts that contribute to the spread of infectious diseases. The emerging view is that the indoor environment and indoor gathering present a spreading risk as virus-laden aerosol lingers in indoor air for hours at high concentration. Accumulated exposure to viral load over time is an important risk determinant for an individual to be infected. The central building management systems could provide a potential means to monitor, reduce, and control such spread. Closed-loop circulation systems in these buildings give longitudinal monitoring mechanisms for ascribing disease spread to local events. Through a case study with the implementation of such monitoring and control in a real-life commercial building, we explore how recent advances in metadata modeling and application programs in buildings can be applied to achieve a new capability for *zonal* air handling and thus reach a higher air quality guarantees expressed in terms of air change rates than currently possible in building-level air control. Based on these experiments, we observe challenges and opportunities in indoor-climate control as a three-way tradeoff between safety, occupant comfort, and energy costs.

CCS CONCEPTS

• **Hardware** → **Power and energy**; • **Computer systems organization** → **Sensor networks**.

KEYWORDS

Smart buildings, air handling, safety, energy efficiency

ACM Reference Format:
Xiaohan Fu, Jason Koh, Francesco Fraternali, Dezhi Hong, Rajesh Gupta. 2020. Poster Abstract: Zonal Air Handling in Commercial Buildings. In *The 7th ACM International Conference on Systems for Energy-Efficient Buildings, Cities, and Transportation (BuildSys '20), November 18–20, 2020, Virtual Event, Japan.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3408308.3431113

1 INTRODUCTION

In view of the current COVID-19 pandemic caused by the spreading SARS-CoV-2 virus, a number of efforts are underway to control its spread. Key findings among these are the role of individual 'super-spreaders' and exposure to viral loads via aerosols and droplets over time in indoor environments [5]. These two observations have a direct implication on our testing/tracing protocols and how indoor facilities are organized and operated to minimize the environmental risk of contracting the disease in places such as classrooms and corridors. This risk is estimated as a function of the volume of the room, the number of persons, their aerosol emission (i.e. activity level and type), temperature/humidity, and airflow (room layout, vent locations, thermal circulations, etc). The operation of the HVAC system provides a critical means to reduce the likelihood of spreading events where the contaminant is added by occupants and removed through HVAC.

Traditional research and practice for building control are focused on optimizing energy efficiency and thermal comfort [2–4]. When adding a third "objective" of safety into the optimization equation, existing optimization methods and solutions to air handling do not well suit the need with many unknowns remaining. For example, one of the recommended measures is to increase the air circulation rate. However, there are many practical challenges and considerations in achieving a higher air change (ACH) rate. In this study, we demonstrate how to realize increased air circulation in a building, empirically explore the impact of such operation on the building, and discuss implications of increased air handling by zones on building operating conditions.

2 EXPERIMENT AND RESULTS

2.1 Experiment Protocol and Implementation

We focus on measures to increase air circulations by real-time control of airflow across various zones and observe how that would impact thermal comfort and energy consumption. Our experimental protocol is as follows:

- Control variables: supply air temperature (SAT) of AHU, economizer of AHU, airflow of VAV in individual rooms
- Control plan: SAT at 60F and 65F for AHU, economizer set to use 100% outside air, max airflow for VAVs per their limit
- Types of zones for the experiment: classrooms, student labs, and conference room; seven in total
- Observables: temperature and CO_2 , humidity (when available) in each room, total energy consumption of the building

All experiments were conducted in an office building at UC San Diego with a program built upon Brick [1].

2.2 Preliminary Results and Discussions

In the first set of experiments, we examine the impact of high supply airflow on thermal comfort level and HVAC equipment in one classroom. Specifically, we picked three two-hour intervals in the day when we set the VAV supply airflow of that room to the maximum and observed the response of several phenomena as illustrated in Figure 1. In the remaining time, the default control logic was used. Regarding the achievable ACH rate, the default HVAC control strategy provides an ACH rate at around 5 which

BuildSys '20, November 18–20, 2020, Virtual Event, Japan

ACM ISBN 978-1-4503-8061-4/20/11 . . . $15.00
https://doi.org/10.1145/3408308.3431113

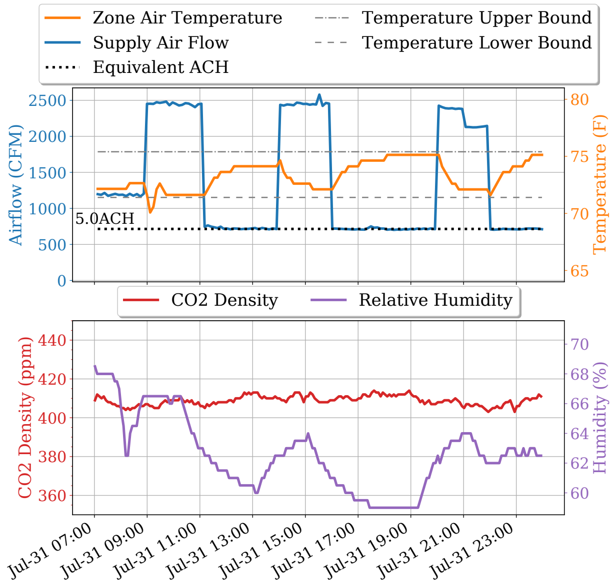

Figure 1: A classroom with three high-ACH sessions with supply air temperature of 60F used.

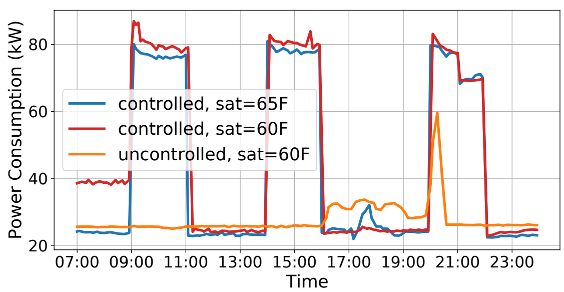

Figure 2: Power consumption of a classroom for experiment on three different days with similar weather.

falls short of the target rate for offices for safe occupancy. Ideally, we want to seek substantially higher ACH rates for all classrooms (e.g., close to 12 ACH which is employed in hospitals for infection isolation). This is shown to be possible in Figure 1 for a single classroom. The CO_2 density turns out to be at a stable level, which might be misleading as we do not have any occupancy. We also present in Figure 2 the power consumption of the classroom, along with an uncontrolled baseline day. We see that increased airflow rate leads to higher energy consumption, so did using cooler air.

We also observe that while the room temperature remained in the desired range (refer to the upper and lower limits in Figure 1), increasing the SAT to 65F (as opposed to the default setting of 60F) could result in overheated spaces such as server rooms which generate excessive heat and require lower SAT. Also, the building in the experiment is located in a temperate climate where using complete outside air does not stretch the limit of the central AHU. This may not be feasible in hotter regions. In addition, these experiments were conducted with *no* occupancy (due to ongoing closure of buildings to normal occupancy). It remains a question whether our hypothesis and observations would still hold when the building sees actual occupants. Specifically, the CO_2 density trending is of special interest. Also, the effect of high ACH control on an entire building remains yet to be investigated.

2.3 Planned Deployment using Brick Schema

Based on our verification of safety-aware control, we plan to deploy additional application logic across multiple buildings using Brick to standardize discovery, access, and control of resources. The algorithm proceeds as follows: 1) A user designates a target zone (e.g., Room-101); 2) Calculate the remaining capacity of AHU (such as airflow and cooling); 3) Identify the maximum mechanical airflow limit of the terminal unit of the zone; 4) Identify the airflow setpoint of the target zone; 5) Change the setpoint value in the controller.

The percentage of AHU capacity used, which requires to understand the relations among a target zone, its associated AHU, and all the VAVs associated with the AHU, can be achieved with standard SPARQL queries, as shown in Listing 1.

Listing 1: A SPARQL Query for Calculating AHU's Current Capacity

```
prefix brick: <https://brickschema.org/schema/1.1/Brick#>
prefix brick-ext: <https://brickschema.org/schema/1.1/BrickExtension#>

select ?ahu ?ahu_limit ?vav_saf ?vav_limit where {
  BIND (<ZONE_ID> AS ?zone )      # [1]
  ?ahu  a              brick:AHU.  # [2-1]
  ?ahu  brick:feeds+  ?zone.      # [2-2]
  ?ahu  brick:feeds+  ?vav.       # [3-1]
  ?vav  a              brick:VAV.  # [3-2]

  # An extension of Brick for representing properties of devices.
  ?vav  brick-ext:mechanicalairflowLimit  ?vav_limit.  #[4-1]
  ?ahu  brick-ext:mechanicalairflowLimit  ?ahu_limit.  #[4-2] }
```

3 CONCLUSION AND FUTURE WORK

Existing building control is designed to meet occupants' thermal comfort while minimizing energy costs. With a new dimension of safety to consider, we need substantially higher airflow rate, which brings in new challenges to thermal comfort conditions and energy efficiency. While our preliminary experiment shows that it is possible to achieve the airflow rate recommended in a couple of rooms, deeper and more comprehensive experiments are required to examine the potential impact in face of actual occupants.

ACKNOWLEDGMENTS

The work was sponsored by the CONIX Research Center, one of six centers in JUMP, a Semiconductor Research Corporation (SRC) program sponsored by DARPA.

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