Decentralized Control of HVAC Considering Thermal Comfort & IAQ*

SinBerBEST — Building Efficiency and Sustainability in the Tropics

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❖ Background & Motivation

- High building energy consumption (50%+ in SG)
- 60%+ caused by HVAC systems

❖ Objectives: To facilitate energy-efficient buildings by developing scalable control methods for HVAC systems, so as to

- Minimize HVAC energy cost
- Maintain thermal comfort & indoor air quality (IAQ)

❖ Challenges

- Conflicting objectives and constraints due to thermal comfort and IAQ
- Nonlinear & nonconvex optimization problem
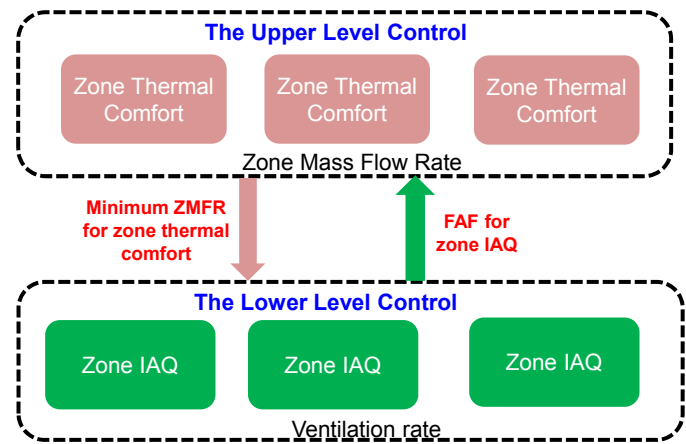- Various decision variables to be coordinated
- Various couplings

❖ HVAC System for Multi-zone Buildings
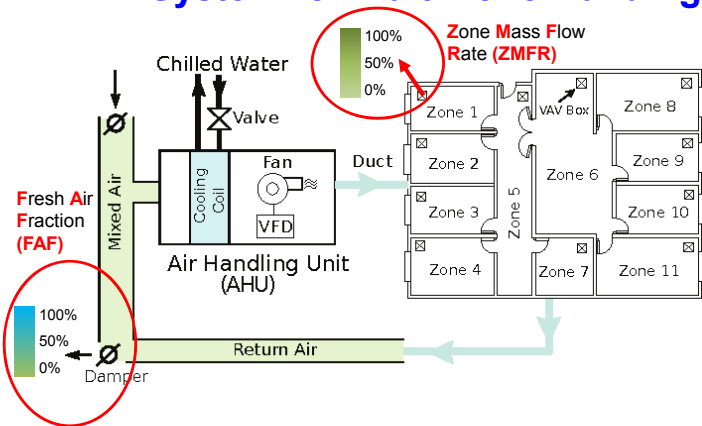
❖ Hierarchical Decentralized Method

- **The Upper Level Control:** zone thermal comfort
  - ✓ Accelerated Distributed Augmented Lagrangian (ADAL) method for nonconvex problems

- **The Lower Level Control:** zone IAQ
 - ✓ Decentralized convex optimization

The Upper Level Control — Zone Thermal Comfort / Zone Mass Flow Rate

Minimum ZMFR for zone thermal comfort — FAF for zone IAQ

The Lower Level Control — Zone IAQ — Ventilation rate

❖ Our Results

Method	Cost (s$)					Thermal comfort	IAQ
	# zones						
	2	10	20	50 (x10³)	100 (x10³)		
No IAQ	98.9	162.9	507.8	1.6	2.9	✓	✗
Centralized Method	100.5	--	--	--	--	✓	✓
Hierarchical Decentralized	102.7	184.9	564.4	1.7	3.0	✓	✓
DCV* I	106.2	184.9	601.7	1.8	3.1	✓	✓
DCV* II	106.6	181.6	593.2	1.8	3.2	✓	✓

* Demand controlled ventilation (DCV)

Zone Temperature

Zone CO_2
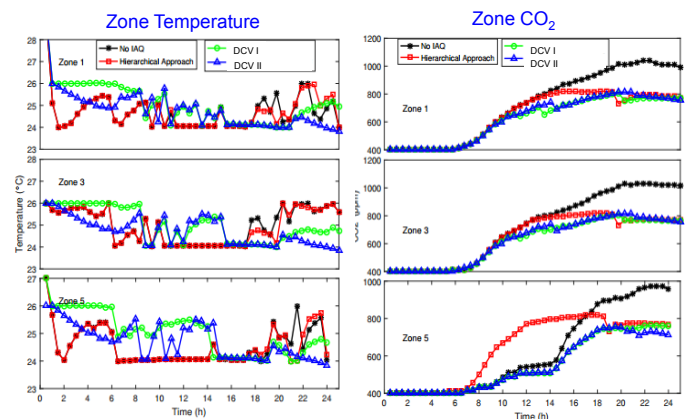
❖ Conclusions

- There is a minor increase of energy cost due to ventilation to guarantee IAQ.
- The sub-optimality of the *Hierarchical Decentralized Method* is less than **2%**.
- **5%-11%** energy cost due to ventilation is reduced compared with DCV strategies.
- Our method is **scalable** to buildings with 100+ zones.

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