Effective Smart Fan Deployment in NUS SDE Net-Zero Building

Supervisor: Assoc Prof Roger ZIMMERMANN
Presentor: ZHONG Sailin

Background

SDE Net-Zero Building as a living lab to promote research collaboration

Elevated air speeds from ceiling fans for hybrid cooling

Energy use and occupant comfort balance

Image source: http://www.serie.co.uk/projects/8/school-of-design-environment#7

Objectives

•Design the **system architecture** that includes a **gateway** to interface with the smart fans, external constraints (such as user locations), and end users (via a mobile application).

•Develop a **new mobile control application** that connects with the gateway. Design an interaction mode that allows students to **collectively control** group of fans in an **energy sustainable** oriented way.

•Design and implement a **data collection system** for future analysis and learning opportunities when the building is open to public.

NUS National University of Singapore

Related Works

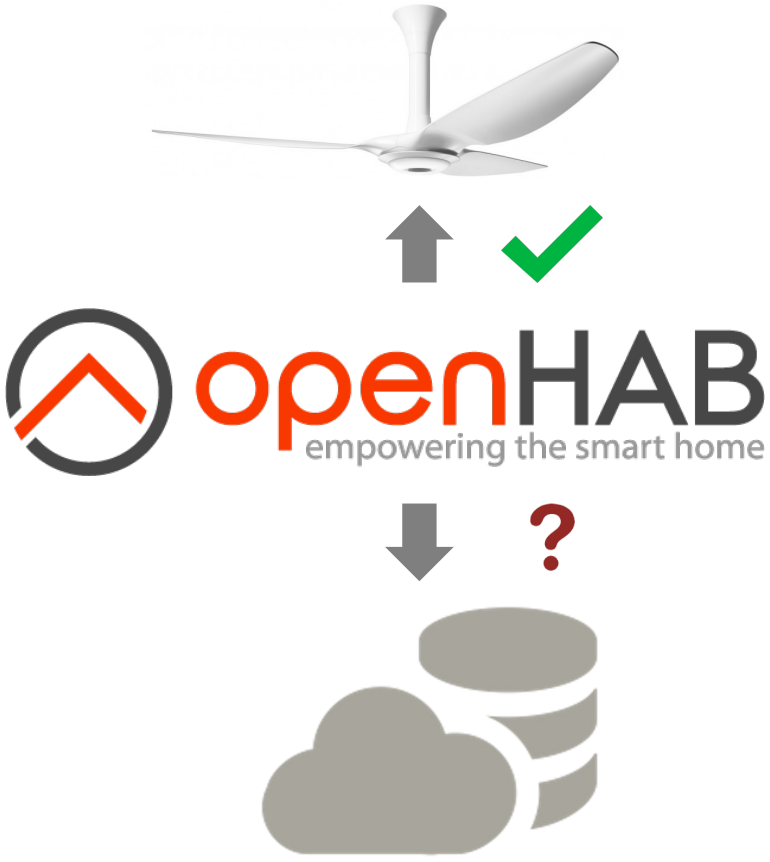
Home Automation Solutions

Name	Open Source	Offer BMS Services	OSI Layers Defined	Support Demand Response
Apple HomeKit	-	✓	⑤ - ⑦	-
Samsung SmartThings	-	✓	⑤ - ⑦	-
OpenHAB	✓	✓	⑦	-
Fairhair Alliance	-	✓	⑤ - ⑦	-
Thread	✓	-	③ - ④	-
Volttron	✓	-	⑦	✓
Weave	✓	-	⑤ - ⑦	-
AllJoyn by AllSeen Alliance	✓	-	⑤ - ⑦	-
Open Interconnect Consortium	✓	-	⑤ - ⑦	-
openADR	✓	-	⑦	✓
ZigBee	✓	-	③ - ⑦	-
Z-Wave	-	✓	① - ⑦	-
LoRa	-	-	① - ②	-
SigFox	-	-	① - ②	-
EnOcean	✓	-	① - ③	-
IEEE 802.15.4	✓	-	① - ②	-
IEEE 802.11 (WiFi)	✓	-	① - ②	-
6LoWPAN	✓	-	③	-

- Open source
- Targeting at application layer
- Available with smart fan binding

Reference: Lilis, G., Conus, G., Asadi, N., and Kayal, M.: 'Towards the next generation of intelligent building: An assessment study of current automation and future IoT based systems with a proposal for transitional design', Sustainable cities and society, 2017, 28, pp. 473-481

Open Source IoT Technology: Node-RED



Node-RED

- Visually programmable
- Available with multiple “nodes” for cloud databases
- Linux compatible

Reference: https://nodered.org/

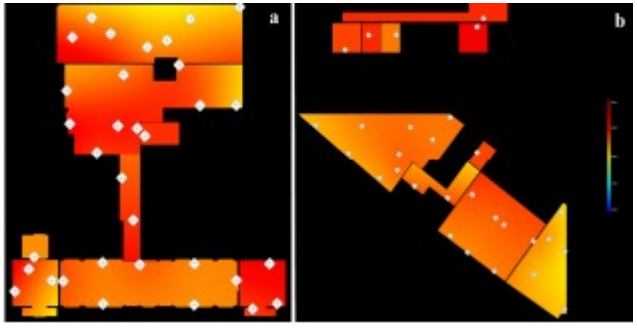
Eco-feedback Technologies

Eco-feedback persuasion strategies

- **Social comparisons**: exposing networked users normative eco-feedback (Jain et al. 2013)
- **Goal-setting**: household receiving a difficult goal and feedback conserved more energy (Becker, 1978), and users are motivated when they feel the importance of the goal and believe the goal can be attained (Locke and Latham, 1991)
- **Rewards and penalties***:* game-like consequence motivation techniques could promote behaviours (Bang, 2007)

Participatory sensing

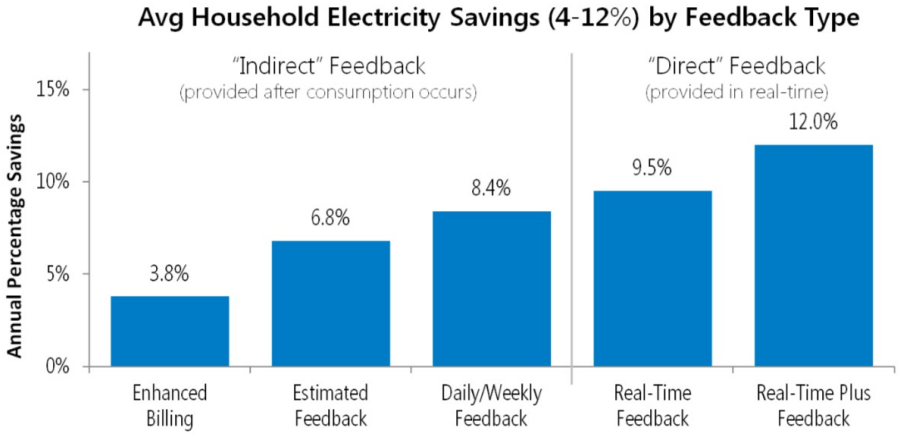
- **Logging**: users thermal comfort information in shared environment could be gathered by distribute distinct QR code in different location (Snow et al.,2017)

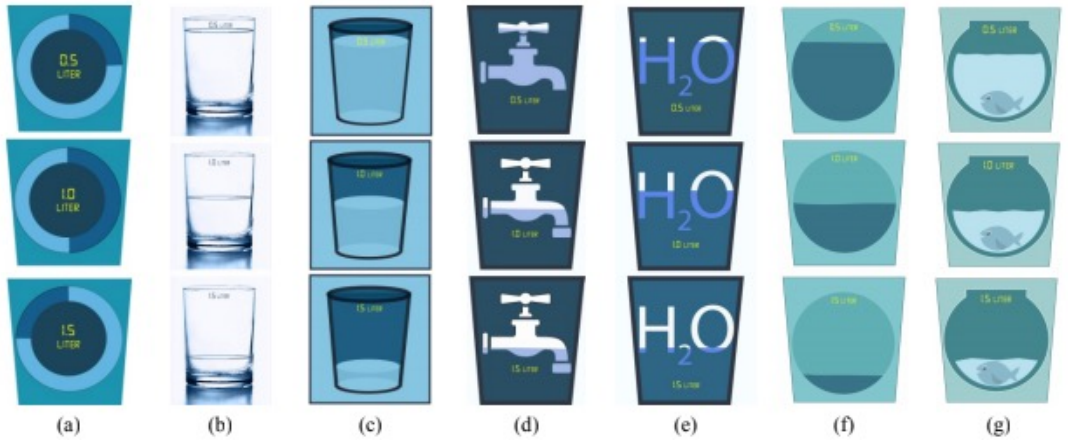


Eco-feedback Technologies

Design space and graphics

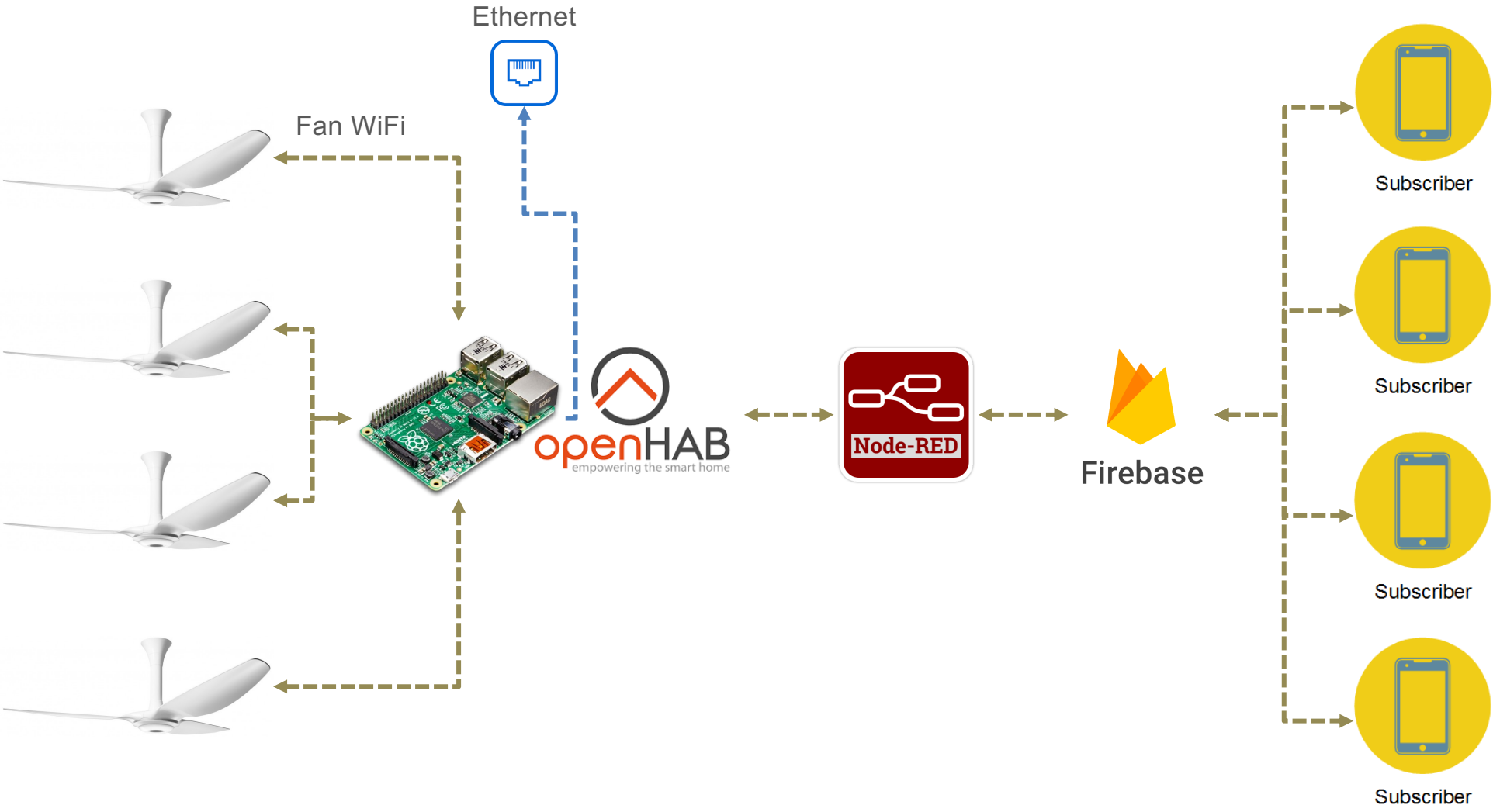
- **Temporal impact***:* real-time feedback encourages more savings (Froehlich, 2011)
- **Visual representation***:* Major design styles are (a) Text and Graph style (b) Realistic style (c)Iconic Style (d) Indexical Style (e) Symbolic Style (f) Abstract style (g) Metaphor using living creatures. Choosing the suitable representation could enlarge the impact on emotion and effectiveness. (Tunprawat et al.,2018)



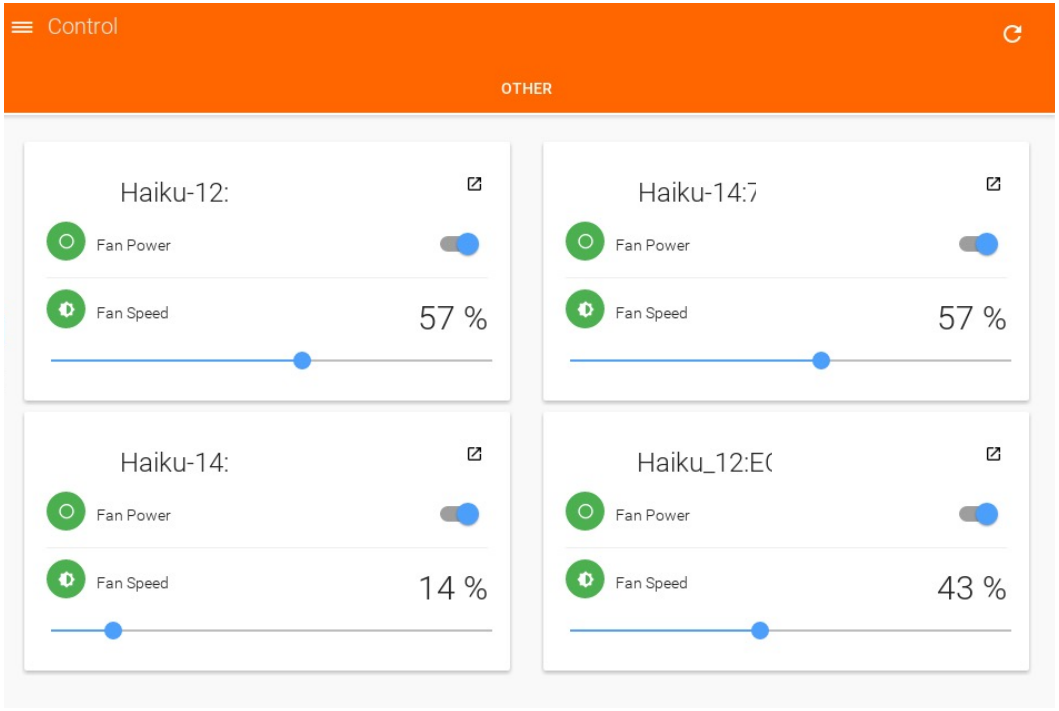


System Architecture

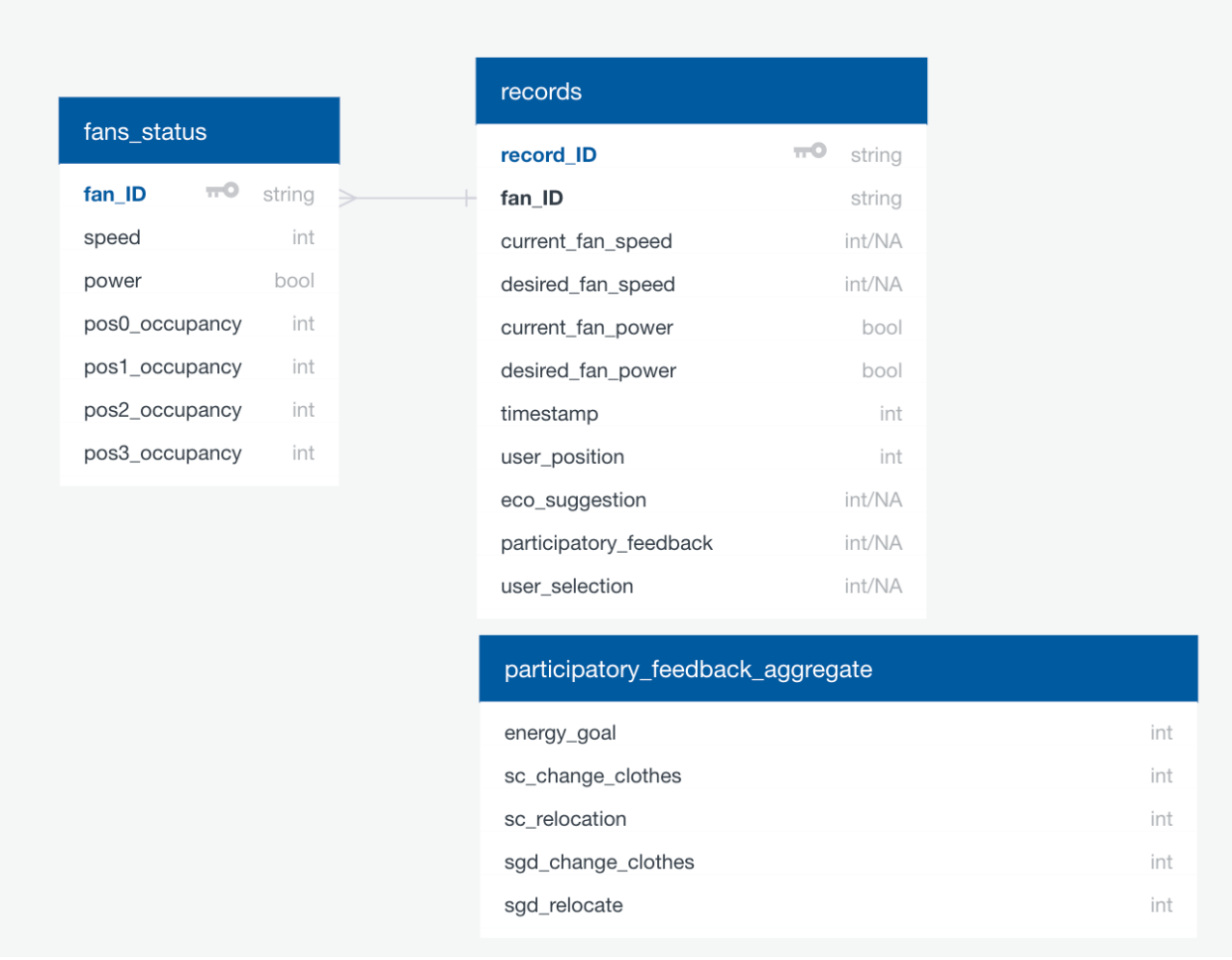
System Architecture

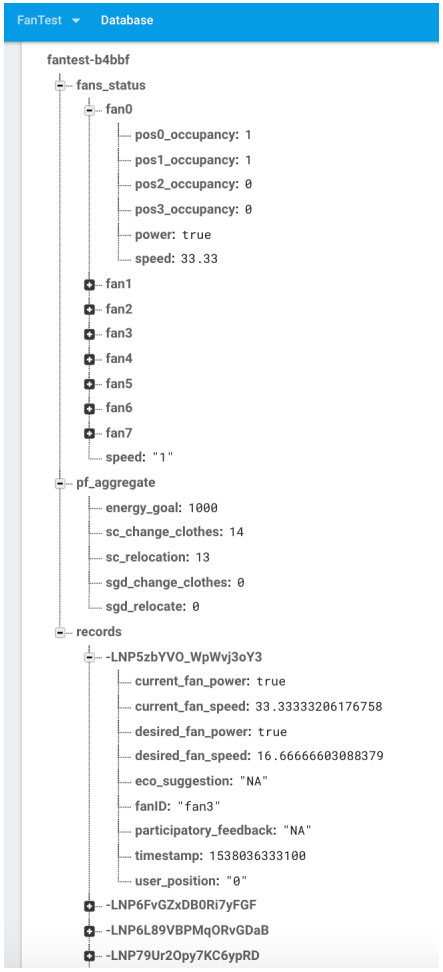


Node-RED and OpenHAB Configurations



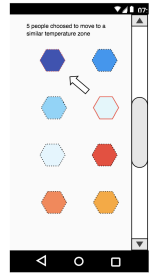
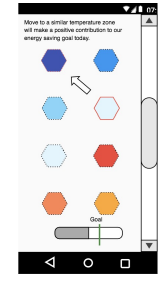
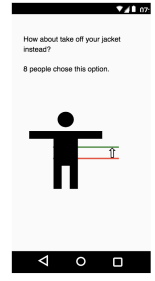
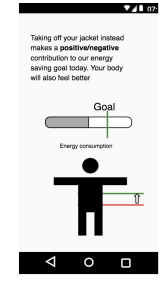
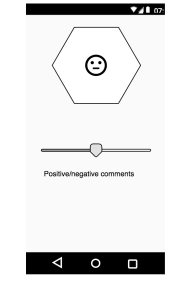
Database Structure



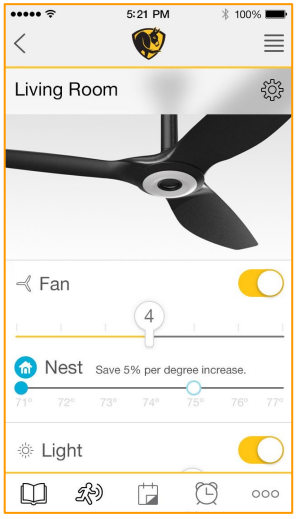


User Interaction

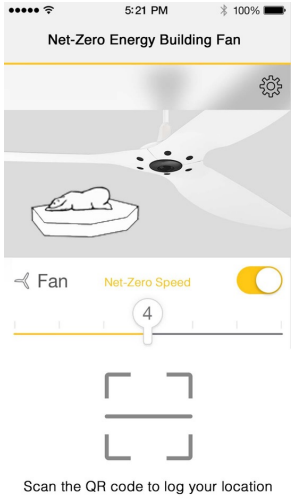
Participatory Eco-feedback

Design dimensions	Participatory feedback		
Eco-suggestions	**Social comparison** *textual*	**Social goal driven** *diagram + textual*	**Reward/punishment** *color + textual*
Relocate *spatial*	spatial + textual (D1) 	spatial + textual + diagram (D2) 	N/A
Change clothes *Symbolic body*	symbolic + textual (D3) 	symbolic + diagram + textual (D4) 	N/A
Change fan speed *living creature metaphor*	N/A	N/A	metaphor/color + textual (D5) 

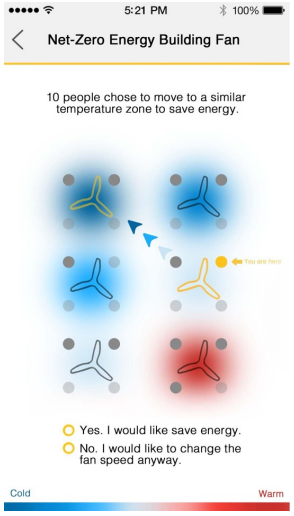
Interface Prototype



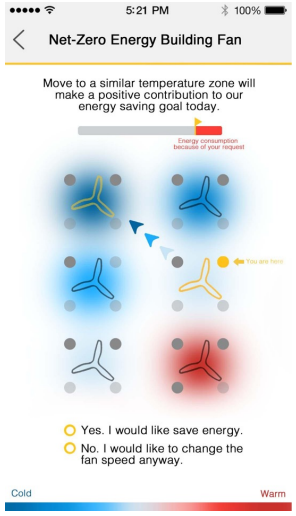
Original fan app



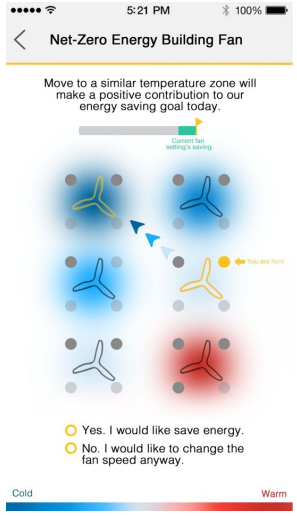
Main



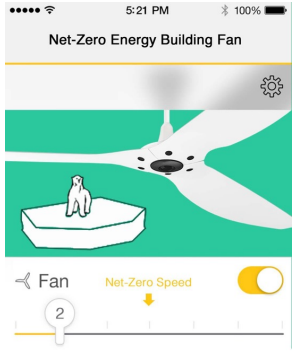
D1



D2.1

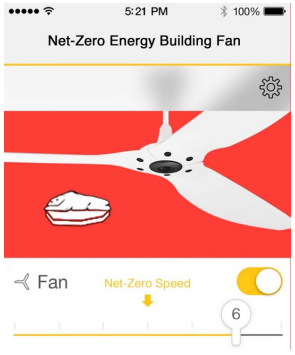


D2.2



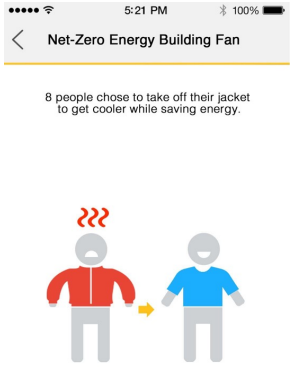
Thank you for lower down the fan speed! This helps us to reduce the energy consumption.

D5.1

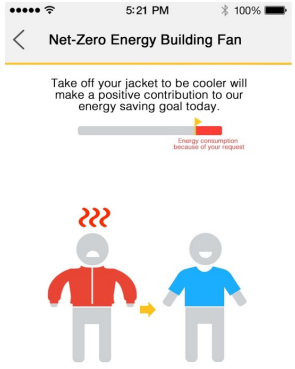


Speed changed as requested but this will require more energy consumption.

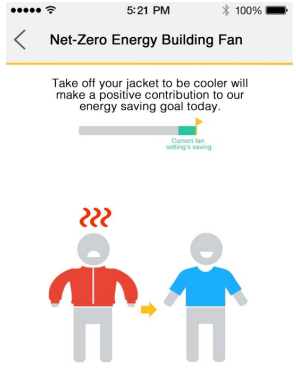
D5.2



D3



D4.1



D4.2

Application Functional Requirements

- The user shall be able to **scan the QR code** to retrieve the latest state of the nearest fan.

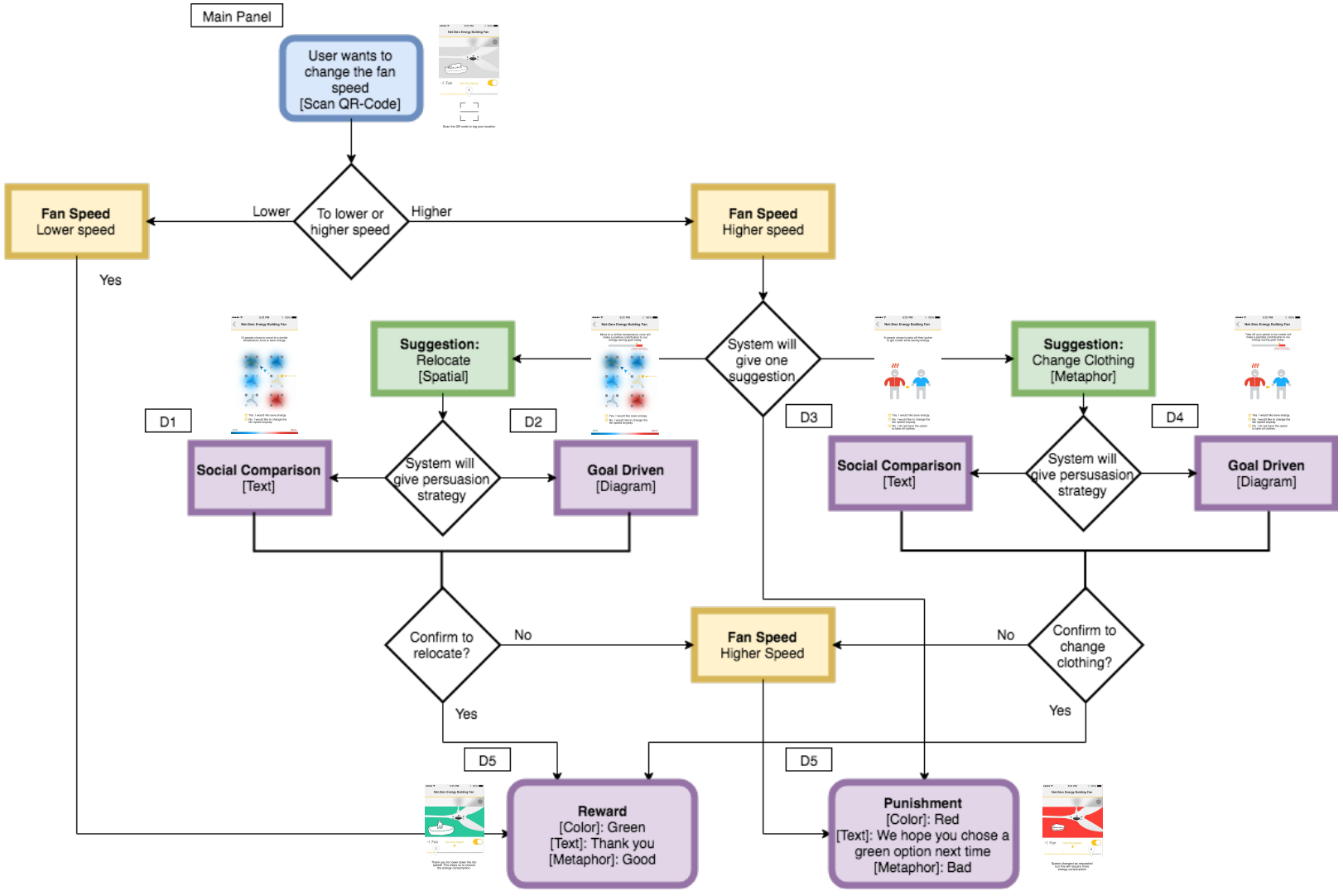
- The application includes a list of **combination of eco-suggestions and participatory feedback** that are randomly combined for the user

- The text and graphic of the eco-feedback interfaces should **update dynamically** according to the others users' usage.

- The user has the **option to accept or deny** an eco-feedback persuasion.

- The user can receive a **state update of the fan** after they submit their choice.

Interaction Flow

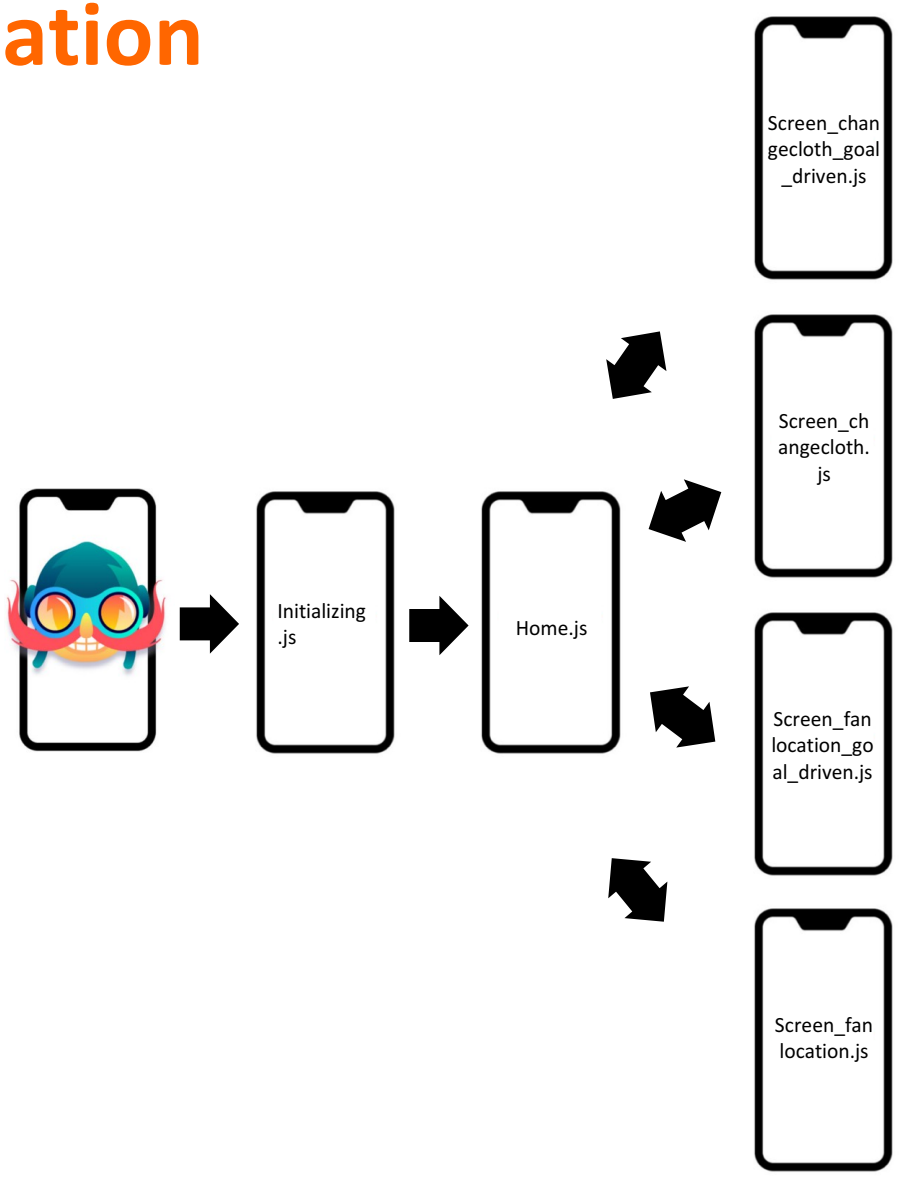


Source: D. Kempenaar

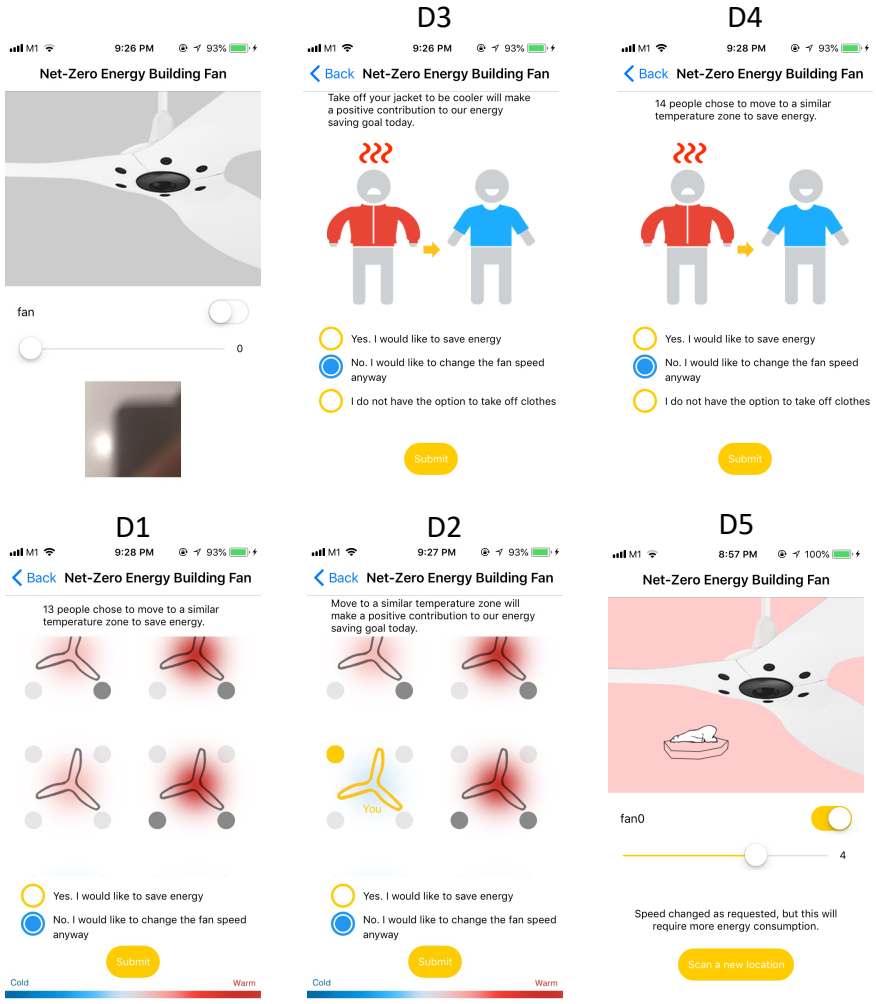
React Native Implementation

- Using *React Native Navigation* solution from Wix for navigation control

- Randomizing a number in Home screen to determine the participatory eco-feedback screen



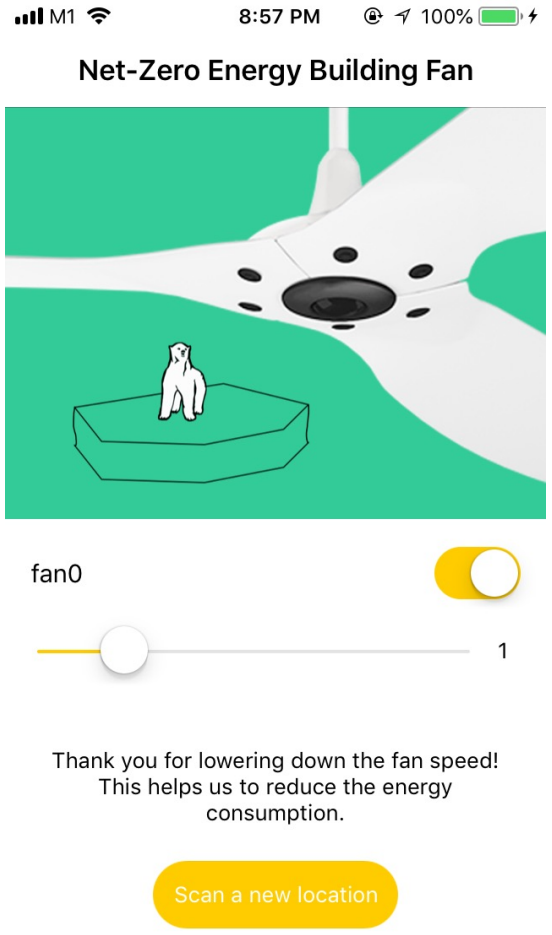
Implemented Interfaces



Application interface when user requests to increase fan speed

First row (left to right): home, Screen_changecloth_goal_driven, Screen_changecloth

Second row: Screen_fanlocation_goal_driven, Screen_fanlocation



Application interface when user requests to decrease fan speed