Semantic Modeling of Smart Homes in the ABS Real-time modeling language

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Outline

- Real-Time ABS language
- The architecture of Smart Home System
- The interactions of each component
- The methods of each component
- Events and their corresponding actions in the Smart Home system
- Simulation results
- Conclusion and future work

Real-Time ABS language

- Real-Time Abstract Behavioral Specification
- A formal, executable, object-oriented language
  - with a Java-like syntax and a formal semantics
- Designed for modeling distributed systems
  - concurrent object groups (COG)
  - deployment component (DC)
- A formal executable framework ABS-SHS for modeling Smart Home System.
- The goal is to help users to make their deployment decisions when they design their Smart Home system.

The architecture of Smart Home System

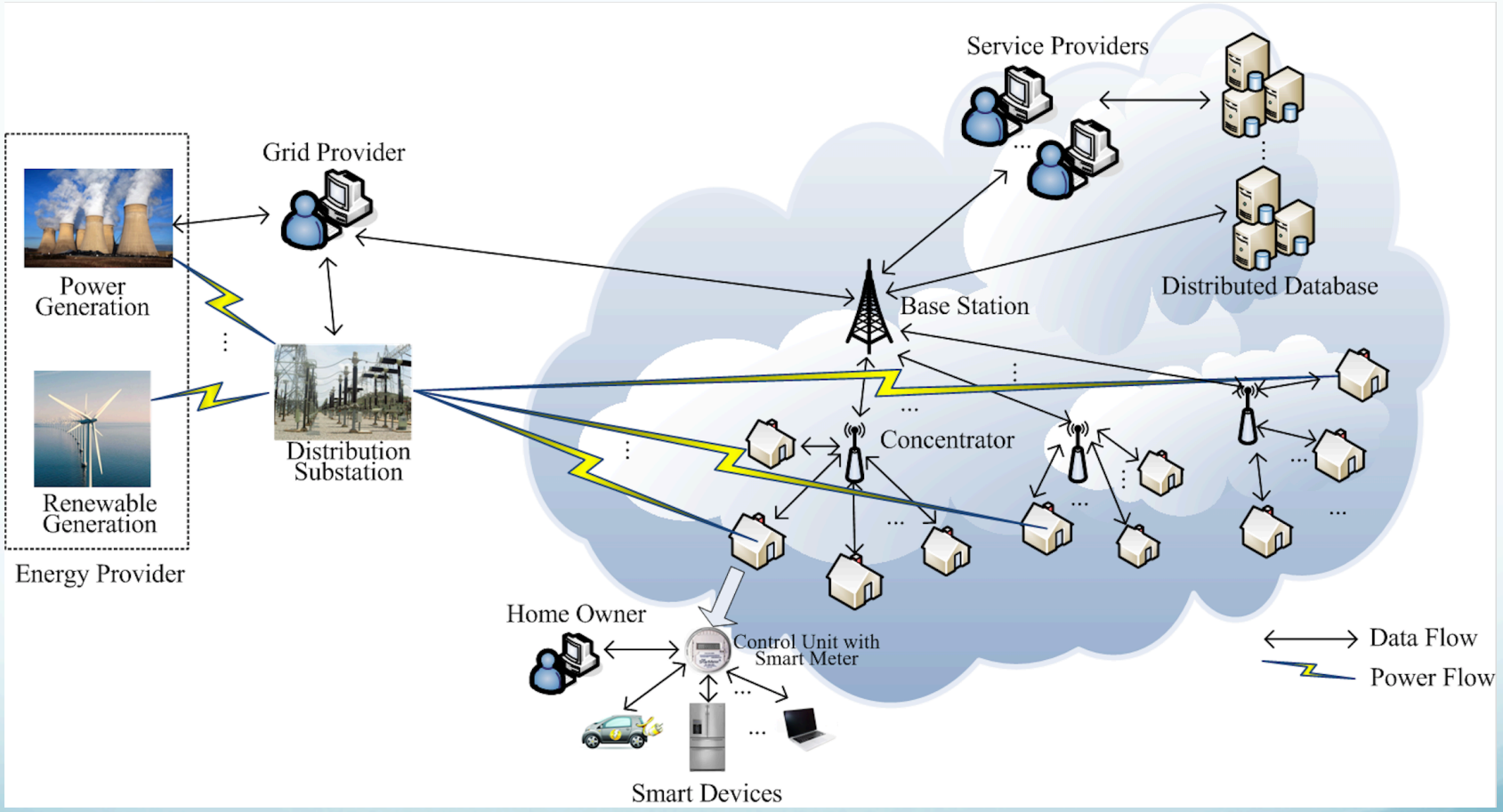

Figure 1: The architecture of Smart Home System

The interactions of each component

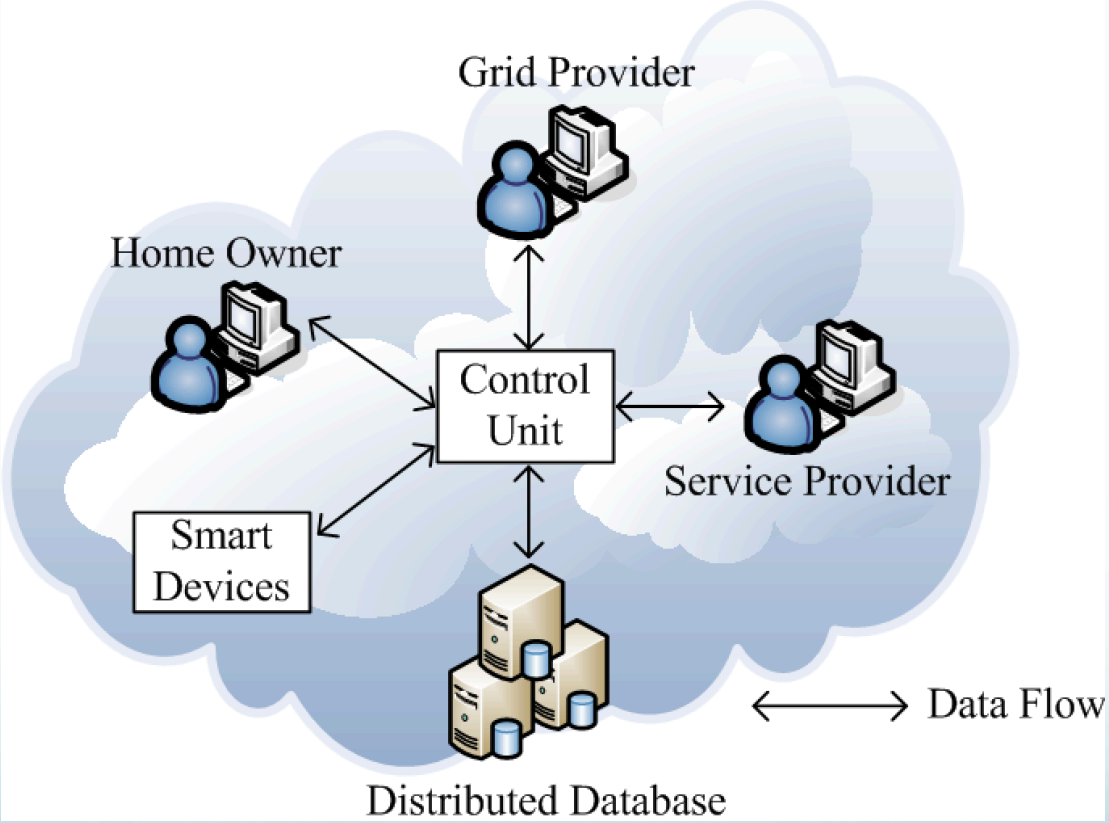

Figure 2: The interactions of each component in ABS-SHS

The methods of each component

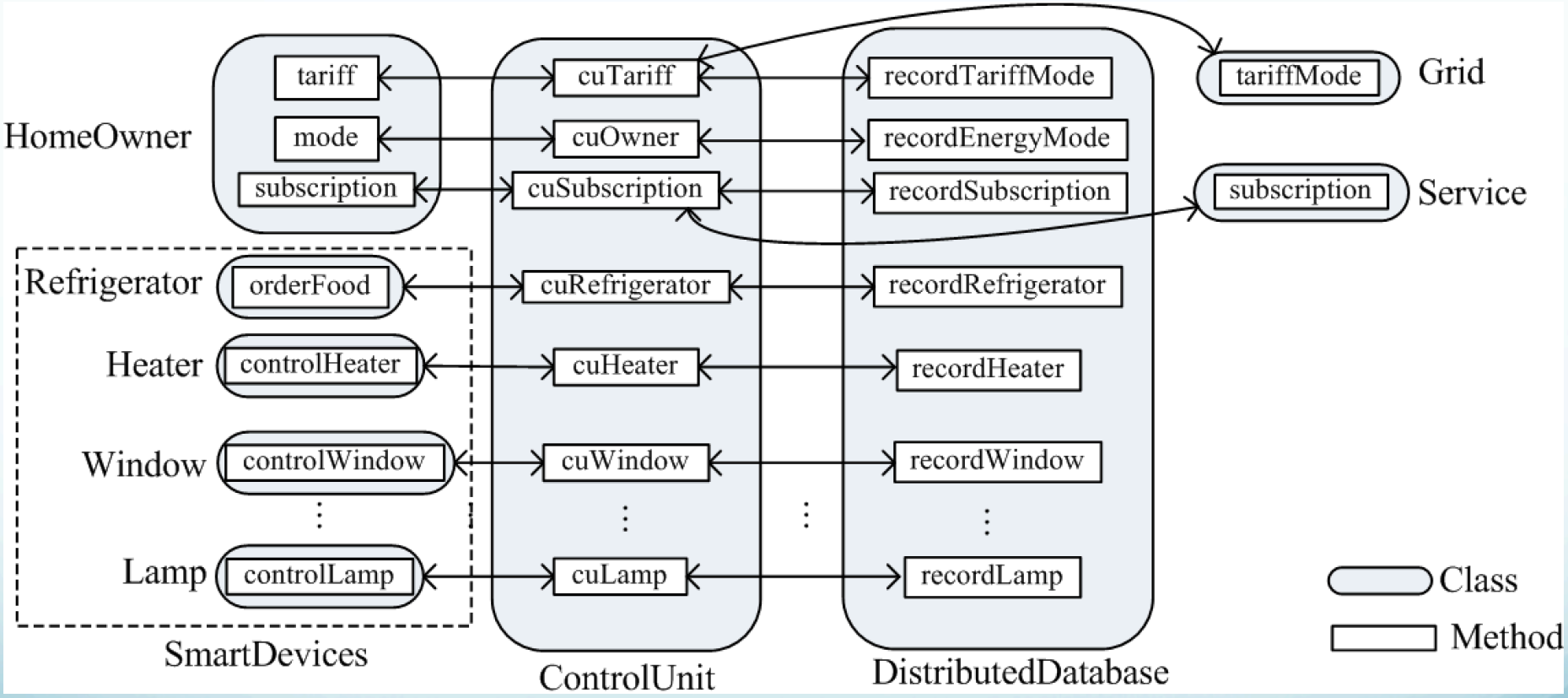

Figure 3: The methods of each component in ABS-SHS

The methods of HomeOwner and ControlUnit

```
interface HomeOwner{
  Unit tariff(String tariff,ControlUnit cu, Grid grid
       DBase dbase);
  Unit mode(ControlUnit cu, DBase dbase);
  Unit subscription(String subscribe,ControlUnit cu,
       Service service, DBase dbase);
}
```

```
interface ControlUnit{
  String cuTariff(String tariff, DBase dbase);
  String cuOwner(String energyMode, DBase dbase);
  String cuSubscription(String subscribe, DBase dbase);
  String cuRefrigerator(String foodName, Int volume,
         String message, DBase dbase);
  String cuHeater(Rat indoorTemp, String message, DBase dbase);
  String cuWindow(Rat outdoorWeather, String message,
         DBase dbase);
  String cuLamp(String switch, String message, DBase dbase);
}
```

The methods of DBase and Grid

```
interface DBase{
    Bool recordTariffMode(String tariffMode);
    Bool recordEnergyMode(String energymode);
    Bool recordSubscriptionScenario(String subscription);
    Bool recordRefrigerator(String name, Int volume,
         String message);
    Bool recordHeater(Rat indoorTemp, String message);
    Bool recordWindow(Rat outdoorWeather, String message);
    Bool recordLamp(String switch, String message);
}
```

```
interface Grid{
    Bool tariffMode(String tariff);
}
```

The methods of Service and Smart Devices

```
interface Service{
   Bool subscriptionScenario(String subscription);
}
```

```
interface Refrigerator{
   Unit orderFood(ControlUnit cu, DBase dbase);
}
interface Heater{
   Unit controlHeater(ControlUnit cu, DBase dbase);
}
interface Window{
   Unit controlWindow(ControlUnit cu, DBase dbase);
}
interface Lamp{
   Unit controlLamp(ControlUnit cu, DBase dbase);
}
```

An event and its corresponding actions

Event	Action
Choosing Tariff	1. tariff of HomeOwner -> cuTariff of cu 2. cuTariff of cu <-> recordTariffMode of DBase 3. cuTariff of cu <-> tariffMode of Grid 4. cuTariff of cu -> tariff of HomeOwner
Choosing Energy model	1. mode of HomeOwner -> cuOwner of cu 2. cuOwner of cu <-> recordEnergyMode of DBase 3. cuOwner of cu -> mode of HomeOwner
Subscribing subscription	1. subscription of HomeOwner -> cuSubscription of cu 2. cuSubscription of cu <-> recordSubscription of DBase 3. cuSubscription of cu <-> subscription of Service 4. cuSubscription of cu -> subscription of HomeOwner
Refrigerator Triggering	1. orderFood of Refrigerator -> cuRefrigerator of cu 2. cuRefrigerator of cu <-> recordRefrigerator of DBase 3. cuRefrigerator of cu -> orderFood of Refrigerator
Heater Triggering	1. controlHeater of Heater -> cuHeater of cu 2. cuHeater of cu <-> recordHeater of DBase 3. cuHeater of cu -> controlHeater of Heater
Window Triggering	1. controlWindow of Window -> cuWindow of cu 2. cuWindow of cu <-> recordWindow of DBase 3. cuWindow of cu -> controlWindow of Window
Lamp Triggering	1. controlLamp of Lamp -> cuLamp of cu 2. cuLamp of cu <-> recordLamp of DBase 3. cuLamp of cu -> controlLamp of Lamp

Table 1: An event and its corresponding actions in ABS-SHS.

Simulation Results of Home Owner's settings

```
//Tariff
TimePoint 0:
  Home owner chooses "Green" tariff.
  *ControlUnit: "Green" and inserts it into DBase.*
  -DBase: the tariff is "Green" (Green|Orange|Red).-
TimePoint 1:
  Grid provider knows home owner's tariff mode is "Green".

//Subscription
TimePoint 0:
  Home owner subscribes "Scenario1" subscription.
  *ControlUnit: "Scenario1" and inserts it into DBase.*
  -DBase: the subscription scenario is "Scenario1".-
TimePoint 2:
  Service provider knows home owner's subscription scenario
  is "Scenario1".

//Energy mode
Time point 0:
  Home owner chooses "Min" energy mode.
Time point 1:
  *ControlUnit: "Min" and inserts it into DBase.*
  -DBase: the energy mode is "Min" in the Smart Home.-
Time point 2:
  Home owner receives a confirmation from ControlUnit.
```

Figure 4: Home Owner's settings in ABS-SHS.

Simulation Results of the Refrigerator

```
Time point 10:
  The sensor of Refrigerator is triggered.
  *ControlUnit: "BuyEggs." and insert it into DBase.*
  -DBase: "Eggs", Volume: 2, "BuyEggs."-
Time point 11:
  Refrigerator sends a "Eggs" message to home owner,
  because he/she only has "2" in the refrigerator.
Time point 42:
  The sensor of Refrigerator is triggered.
  *ControlUnit: "BuyVegetable." and insert it into DBase.*
  -DBase: "Vegetable", Volume: 3, "BuyVegetable."-
  Refrigerator sends a "Vegetable" message to home owner,
  because he/she only has "3" in the refrigerator.
Time point 52:
  The sensor of Refrigerator is triggered.
  *ControlUnit: "BuyDrink." and insert it into DBase.*
  -DBase: "Drink", Volume: 1, Description:"BuyDrink."-
  Refrigerator sends a "Drink" message to home owner,
  because he/she only has "1" in the refrigerator.
```

Figure 5: The actions of the Refrigerator in ABS-SHS.

Simulation Results of the Heater

```
Time point 3:
  The sensor of Heater is triggered.
  *ControlUnit: "TurningOnTheHeater" and inserts it into DBase.*
  -DBase: Temptature is -4, "TurningOnTheHeater"-
  Heater is turning on, because the temperature is "-4" degrees.
Time point 16:
  The sensor of Heater is triggered.
  *ControlUnit: "TurningOffTheHeater" and inserts it into DBase.*
  -DBase: Temptature is 15, Description:"TurningOffTheHeater."-
  Heater is turning off, because the temperature is "15" degrees.
Time point 20:
  The sensor of Heater is triggered.
  *ControlUnit: "TurningOnTheHeater" and insert it into DBase.*
  -DBase: Temptature is 12, Description:"TurningOnTheHeater."-
Time point 21:
  Heater is turning on, because the temperature is "12" degrees.
Time point 28:
  The sensor of Heater is triggered.
  *ControlUnit: "TurningOffTheHeater" and insert it into DBase.*
  -DBase: Temptature is 16, Description:"TurningOffTheHeater."-
  Heater is turning off, because the temperature is "16" degrees.
```

Figure 6: The actions of the Heater in ABS-SHS.

Simulation Results of the Window

```
Time point 5:
  The sensor of Window is triggered.
  *ControlUnit: "ClosingTheWindow" and inserts it into DBase.*
  -DBase: It is 58% chance of rain, "ClosingTheWindow."-
  Window is closing, because it is a "58"% chance of rain.
Time point 29:
  The sensor of Window is triggered.
  *ControlUnit: "OpeningTheWindow" and inserts it into DBase.*
  -DBase: It is 15% chance of rain, "OpeningTheWindow."-
  Window is opening, because it only is "15"% chance of rain.
```

Figure 7: The actions of the Window in ABS-SHS.

Simulation Results of the Lamp

```
Time point 6:
  The sensor of Lamp is triggered.
  *ControlUnit: "TurningOffTheLamp." and inserts it into DBase.*
  -DBase: Lamp is "off", "TurningOffTheLamp."-
Time point 7:
  Lamp is turning off, because it is "bright".
Time point 13:
  The sensor of Lamp is triggered.
  *ControlUnit: "TurningOnTheLamp." and inserts it into DBase.*
  -DBase: Lamp is "on", "TurningOnTheLamp."-
Time point 14:
  Lamp is turning on, because it is "dark".
Time point 20:
  The sensor of Lamp is triggered.
  *ControlUnit: "TurningOffTheLamp." and inserts it into DBase.*
Time point 21:
  -DBase: Lamp is "off", "TurningOffTheLamp."-
  Lamp is turning off, because it is "light".
Time point 51:
  The sensor of Lamp is triggered.
  *ControlUnit: "TurningOnTheLamp." and inserts it into DBase.*
  -DBase: Lamp is "on", "TurningOnTheLamp."-
  Lamp is turning on, because it is "dark".
Time point 57:
  The sensor of Lamp is triggered.
  *ControlUnit: "TurningOffTheLamp." and inserts it into DBase.*
  -DBase: Lamp is "off", "TurningOffTheLamp."-
  Lamp is turning off, because it is "light".
```

Figure 8: The actions of the Lamp in ABS-SHS.

Conclusion and Future Work (1/2)

- In the research, we have presented the ABS-SHS framework based on the formal modeling language Real-Time ABS.
- With ABS-SHS, users can flexibly configure a smart home system, including:
  - tariff, energy mode, subscription
  - smart devices
  - control unit
  - and distributed database

Conclusion and Future Work (2/2)

- User can easily evaluate and compare the consequences of different deployment decisions in the Smart Home system during the design phase of their smart home applications, to achieve stable execution and cost-effective deployments.

- Demonstrate or verify ABS-SHS through a real Smart Home environment.
- Discuss different deployment decisions in the Smart Home system based on security, privacy, and, energy consumption, performance issues.