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Description	

Real-Time Power Supply and Demand Mediation Algorithm for Energy on Demand System

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Abstract— We proposed the concept of Energy on Demand (EoD) system as novel smart demand-side energy management scheme to realize efficient and versatile control of e-power flows among decentralized energy generation, storage devices and appliances in homes, offices, factories, and neighboring communities. This paper proposes a real-time power supply and demand meditation algorithm based on EoD system. The novelty of our proposed method rests in (i) power allocation based on appliance dynamic priority model (ii) power supply from multiple power sources based on their capacity limitations i.e., load factor profile (iii) multi agent real-time mediation algorithm for efficient management of power.

I. INTRODUCTION

The crucial task of electrical power management systems is to keep the balance between power supply and consumption. The dynamic changing power supply and consumption patterns are most critical issues to be solved. In [1], we proposed a novel demand based energy management system which can guarantee the power reduction without effecting the quality of life for a single power source. In [2], we proposed an augmented EoD system in managing appliances with two power sources i.e., utility power and storage battery. A demand based battery capacity design and dynamic charge/discharge control is introduced. In this particular paper, we augmented our proposed system in managing multiple power sources and appliances in real-time. The efficiency of power sources is checked and power flows are controlled based on capacity of power sources, total power consumption by all appliances and dynamic priority of the appliance.

II. EOD SYSTEM OVERVIEW

Figure 1. shows the basic system architecture for the EoD system which consists of multiple power sources, appliances, and a power manager. A power agent (appliance agent, power source agent) is attached to individual appliance and power source for power consumption/supply monitoring and controlling functions in real-time.

The basic operation of EoD system starts (i) when a home user wants to use an appliance (i.e., switches ON the appliance), the attached appliance agent sends a *power request message* consisting of appliance current priority and requested power level to power manager (ii) Upon receiving request message from appliance, the power manger broadcasts a *start mediation message* to all power sources and appliance (iii) After that, all power agents associated with appliances and power sources send their complete detailed information to the power manager

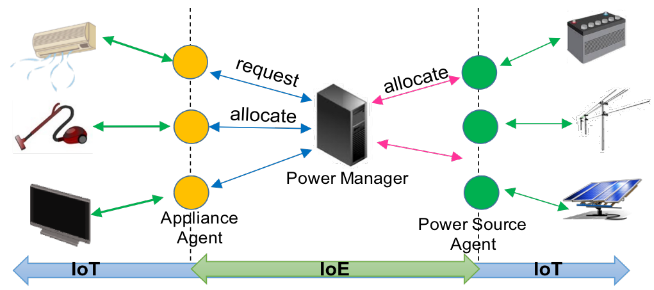

Fig. 1. Energy on Demand (EoD) System overview.

(i.e., *power priority map* from each appliance and *power load profile* from each power source) (iv) Power manager then starts mediation process, which decides how much power should be allocated to the requested appliance based on capacity, availability of the power source, total power consumption by all operating appliances, and requested appliance priority (v) Then, a *power allocation message* is send to the requested appliance and allocated amount of power is supplied to the appliance. If power manager decides to switched OFF the requested appliance, a power allocation message with 0Watt would be sent to the requested appliance.

III. DYNAMIC PRIORITY PROFILE OF AN APPLIANCE

An appliance agent is responsible for real-time power consumption monitoring, controlling, managing dynamic priority profile of an appliance and power request management process. Let AP denote a set of appliances indexed as, $AP_i = \{AP_1, AP_2, \dots, AP_N\}$.

A. Dynamic Priority

When an appliance agent sends a power request message to power manager, the power manager decides the power flow to the appliances based on its priority. We used dynamic priority profile for each appliance to control power flow in real-time. The appliance agent changes appliance priority depending on user's life style pattern, previous day power consumption analysis, and to maintain power consumption limit. Moreover, the dynamic priority of an appliance is monotonically decreasing function. That is, as the power levels are decreasing the priority increases. The dynamic priority uses discrete value ranges from 0 to 1.

B. Power Priority Map

Each appliance agent design a power priority map for individual appliance. A power priority map contains following details of an appliance.

Let $PriM_i$ denote a power priority map of ith appliance as, $PriM_i = \{< ID, opt\_mode, Power\_Level, Pri_i >\}$ Where, ID shows the unique identification number of appliance,

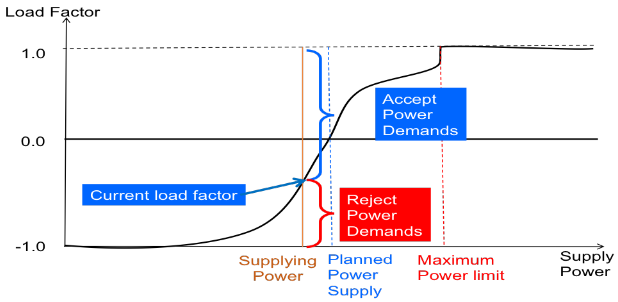

Fig. 2. Load Factor Function of power source.

opt_mode represents current operation mode of the appliance, $Power\_Level$ shows list of all power levels ordered with priority, and Pri_i indicates current priority at that time.

IV. LOAD FACTOR PROFILE OF A POWER SOURCE

A power source agent is responsible for measuring and controlling power supply of the attached power source in real-time. Let PS represents a set of power sources indexed as, $PS_j = \{PS_1, PS_2, \ldots, PS_M\}$

A. Load Factor Function

Each power source agent designs a load factor profile with detailed characteristics of attached power source. Load factor defines the capacity or efficiency of a power source in supplying power. Let LFF_j denote a load factor function of jth power source as, $LFF_j = \{< ID, LFF_j, current\_LF >\}$.Where, ID shows the unique identification number of a power source, LFF_j represents load factor function of the power source, $current\_LF$ indicates current load factor at that time.

In Fig. 2, horizontal axis shows power supply whereas, vertical axis shows load factor which uses continuous value ranges from -1 to 1. The load factor curve implies that the power demands from appliances whose priority values are less than the current load factor of a power source are rejected. Note that, load factor is a monotonically increasing function. That is, the load factor increases as power supply from a power source increases.

V. REAL-TIME POWER MEDIATION PROCESS

The supply demand mediation process starts when EoD system receives all necessary information about power sources and loads. This process uses mediation algorithm given in Fig. 3 to control the power consumptions of appliances. The algorithm can be defined by using load factor profile and dynamic priority profile functions.

A. Mediation Algorithm

Constraint 1:

$$\sum_{i \in N} W(AP_i) = \sum_{j \in M} W(PS_j)$$

Constraint 2:

$$\forall i \in N, \forall j \in M: Pri_i(AP_i) \geq LFF_j(PS_j)$$

As a first step of the mediation algorithm, the total power consumption by all appliances, $\sum_{i \in N} W(AP_i)$, must be equal to

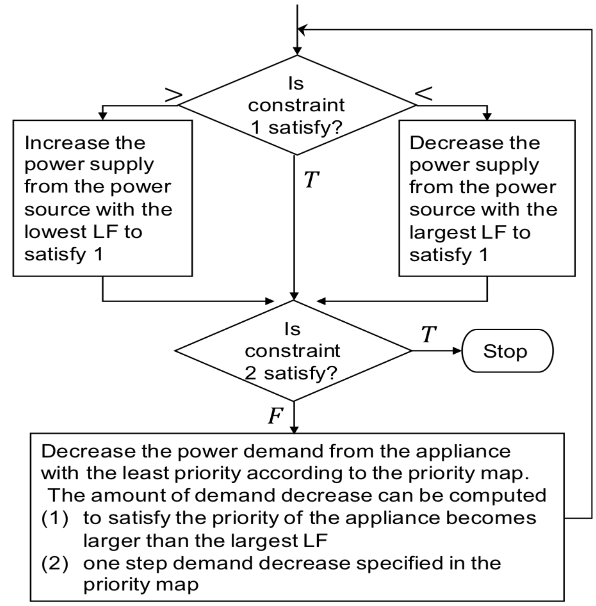

Fig. 3. Power supply and demand mediation algorithm.

the total power supply from all power sources $\sum_{j \in M} W(PS_j)$, i.e., constraint 1 should satisfy all the time in order to maintain power balance. If the total power demand is greater than the total power supply, the power supply will be increase from the power source with least load factor. If the total power demand by appliances is less than the total power supply, the power would be decreased from the power source with the largest load factor to satisfy constraint 1. If constraint 1 is satisfied already, the constraint 2 would be checked next.

Let appliance AP_i with its current priority Pri_i sends a power request message to the power manager. If the priority of the requested appliance is smaller than the load factor the power demand would be decreased from the least priority appliance according to the power priority map. The amount of power to be reduced is one step power demand decrease specified in the power priority map in an iterative manner until constraint 2 satisfied. The mediation algorithm will balance power supply and demand along with efficient power allocation.

VI. CONCLUDING REMARKS

This paper proposed a power mediation algorithm based on EoD system in real-time. The effectiveness of proposed system is already analyzed with couple of real world experiments in smart apartment. The smart apartment is equipped with multiple PSs including utility company, PV power source, battery storage and multiple smart appliances with sensing and controlling abilities. The results of experiments would be presented at the conference presentations.

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