Adaptive Load Management[1]

From the End User, through the Aggregator, to the Wholesale Market and Back

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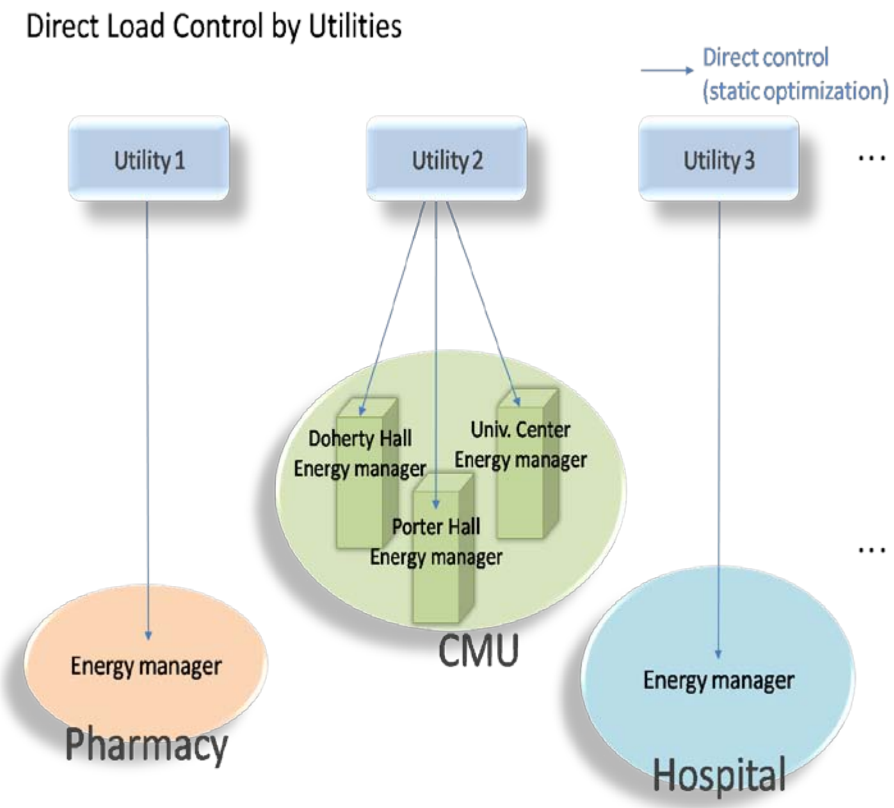
Motivation

- Higher needs for load management resources
  - More uncertainty supply side due to increasing portion of renewable energy sources such as wind power
  - Building generation/transmission capacity becoming more burdensome
- Traditional load management
  - Top-down control from higher level (system operators)
  - Little transparent incentive to end-users to participate
  - No consideration of end-users' different preferences e.g. school and hospital energy needs different

The main ideas

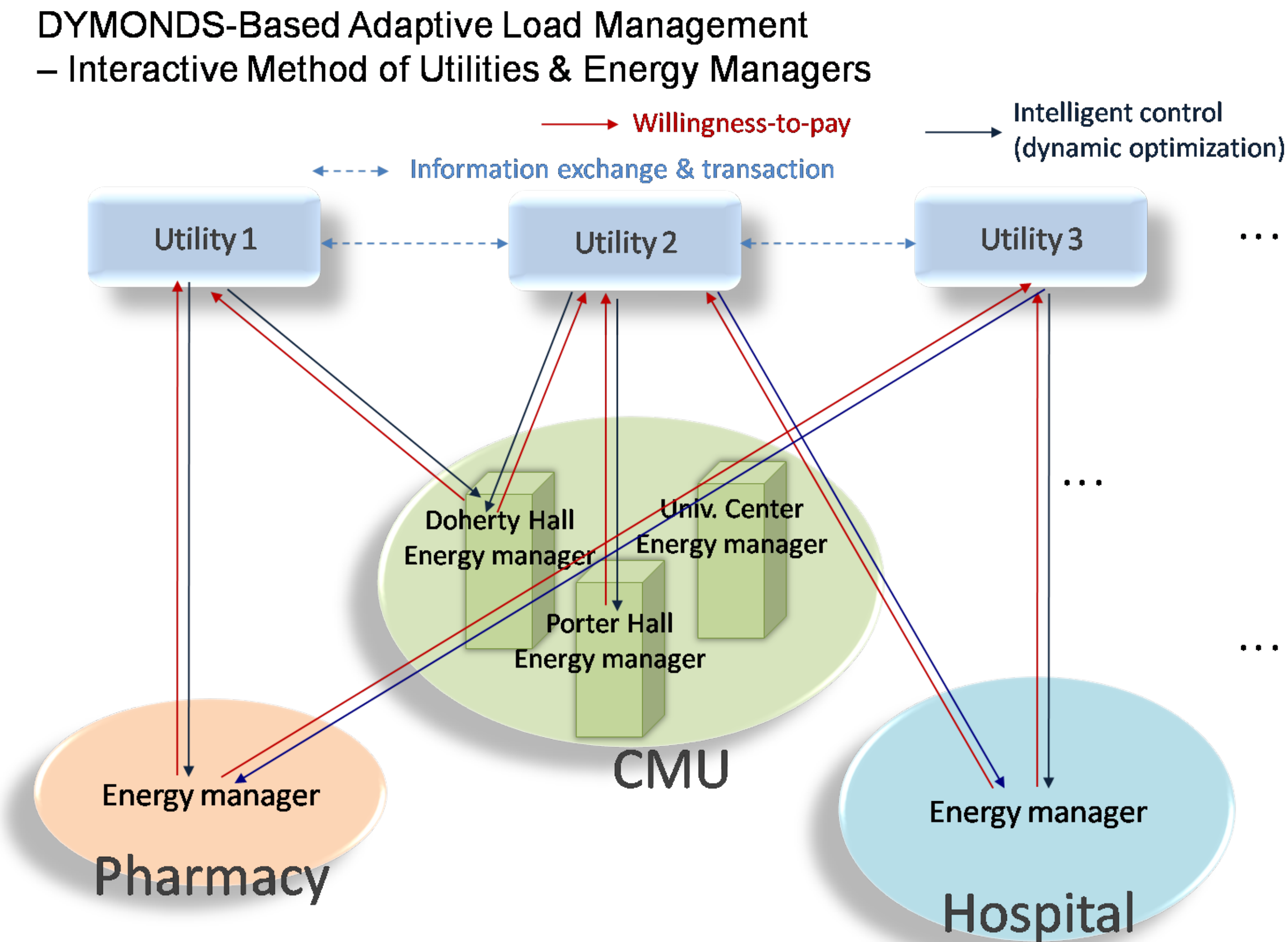
- Incorporate different **end-users' needs and preferences** into load management scheme
  - At some time point, some users are willing to pay a certain price while others are not.
- Mapping preferences into economic preferences
  - Different people have different willingness-to-pay (WTP)'s.
  - WTP
    : maximum monetary amount that an individual would pay to obtain a good
- Top-down control of loads → two-way communicative and adaptive control

Previous load management systems: Direct load control



- One-way flow of information
  - Load management conducted by utilities
  - Top-down control
- Exclusive contracts between supply and demand
- Direct load control
  - Regardless of end-users' preferences
  - No access to market information for end-users/energy managers

Adaptive Load Management



Adaptive Load Management (cont'd)

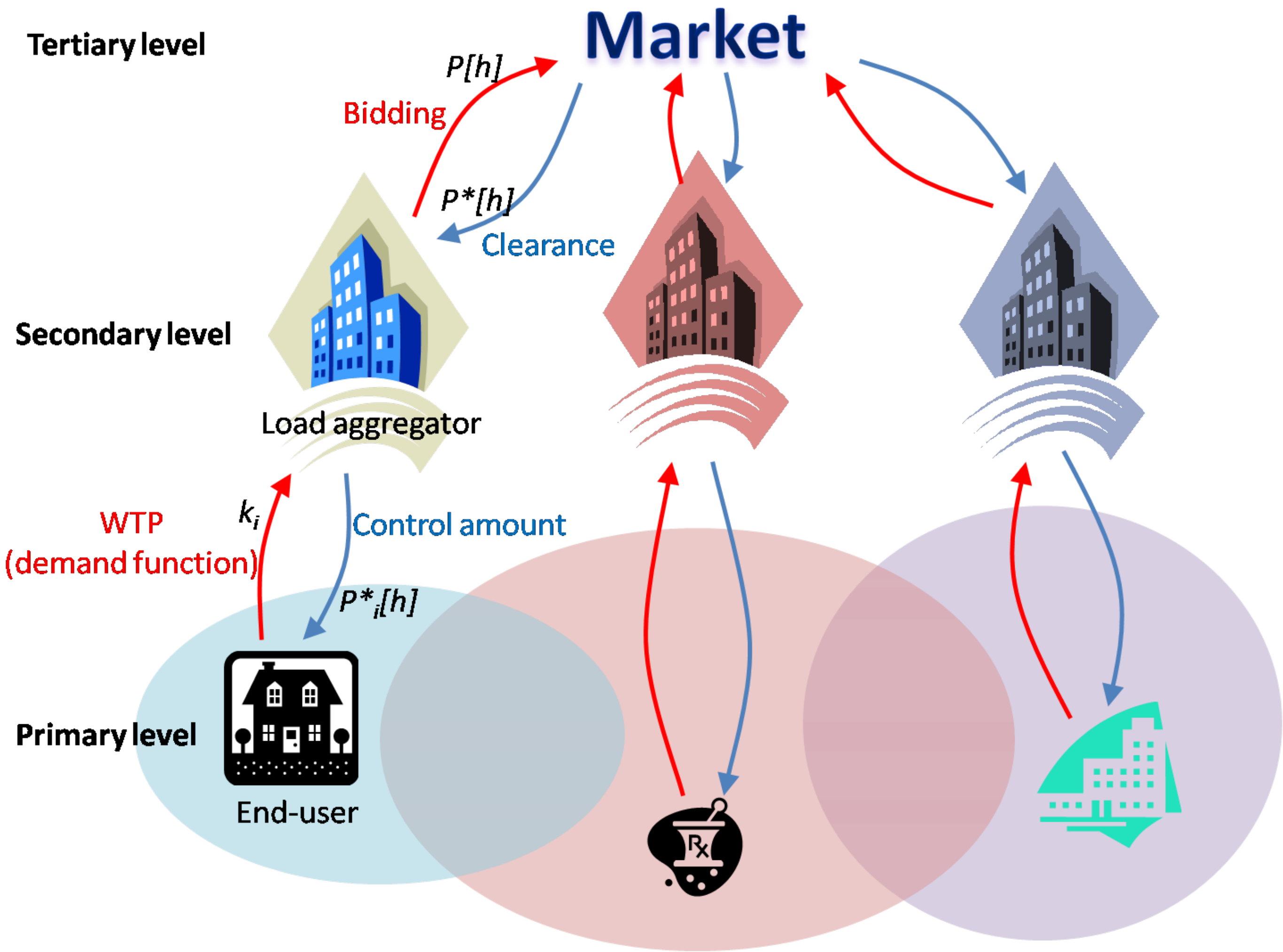
- Two-way flow of information
  - Information of end-users' economic preferences (willingness-to-pay; WTP) sent to higher control level
  - Utility having more information on the lower/ demand level to make

- Multiple contracts (allowed) between supply and demand
  - Competition between utilities for better service
  - Local optimization for more economic transactions on demand side

Adaptive Load Management (cont'd)

- Intelligent load management with more end-users' information
  - Multiple levels of decision-making criteria
  - max {system efficiency}, max {utilities' profits}, min {energy costs of end-users}, max {end-users' benefits}

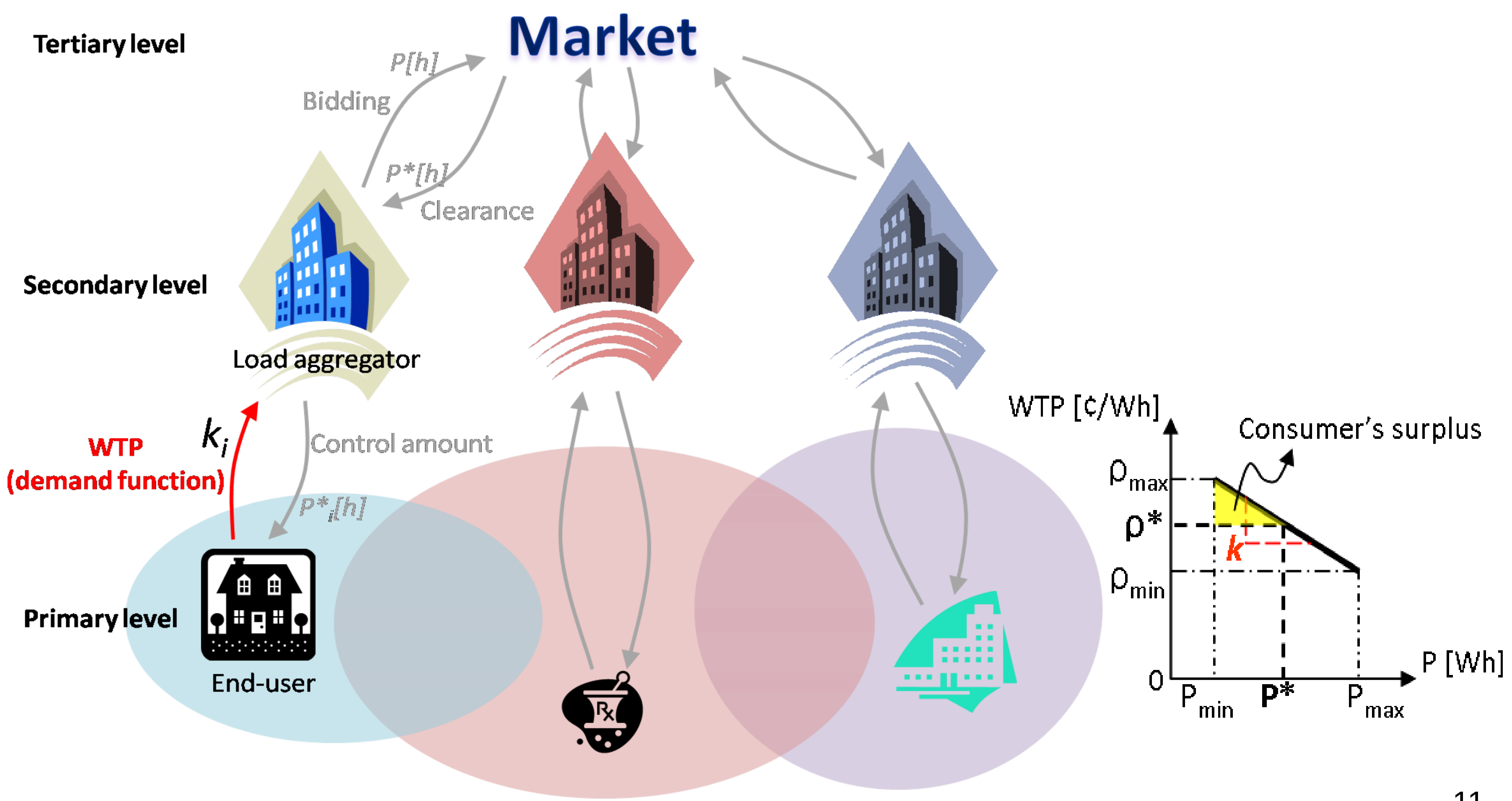
Information flow of Adaptive Load Management



Information flow of Adaptive Load Management (cont'd)

- Primary level (from end-users to load aggregators)
  - Physical preference → economic preference
  - Optimal energy usage
- Secondary level (from load aggregators to market)
  - Optimizing producers' + consumers' surplus
  - Optimal energy usage / market transaction
- Back to primary level (from load aggregators to end-users)
  - Energy usage adapted: allocated by hours
  - Optimal energy usage in a shorter-time interval

Multi-layered adaptive load management – end-users to LAs



Multi-layered adaptive load management – end-users to LAs

- Obtaining individual demand function subject to temperature comfort level

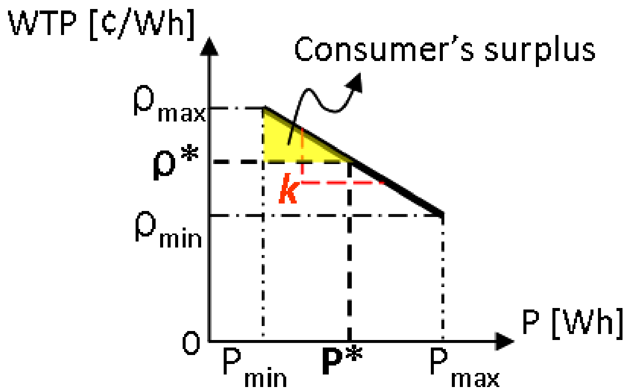
$$\min_{P_i[h]} J_i = \sum_{h=h_0}^{h_0+N} \left[\hat{\rho}[h] \cdot P_i[h] + \left\{ \left(T_i[h] - T_i^{\max}\right)^2 + \left(T_i[h] - T_i^{\min}\right)^2 \right\} \right]$$

where $T_i[h+1] = A_i T_i[h] + B_i P_i[h]$

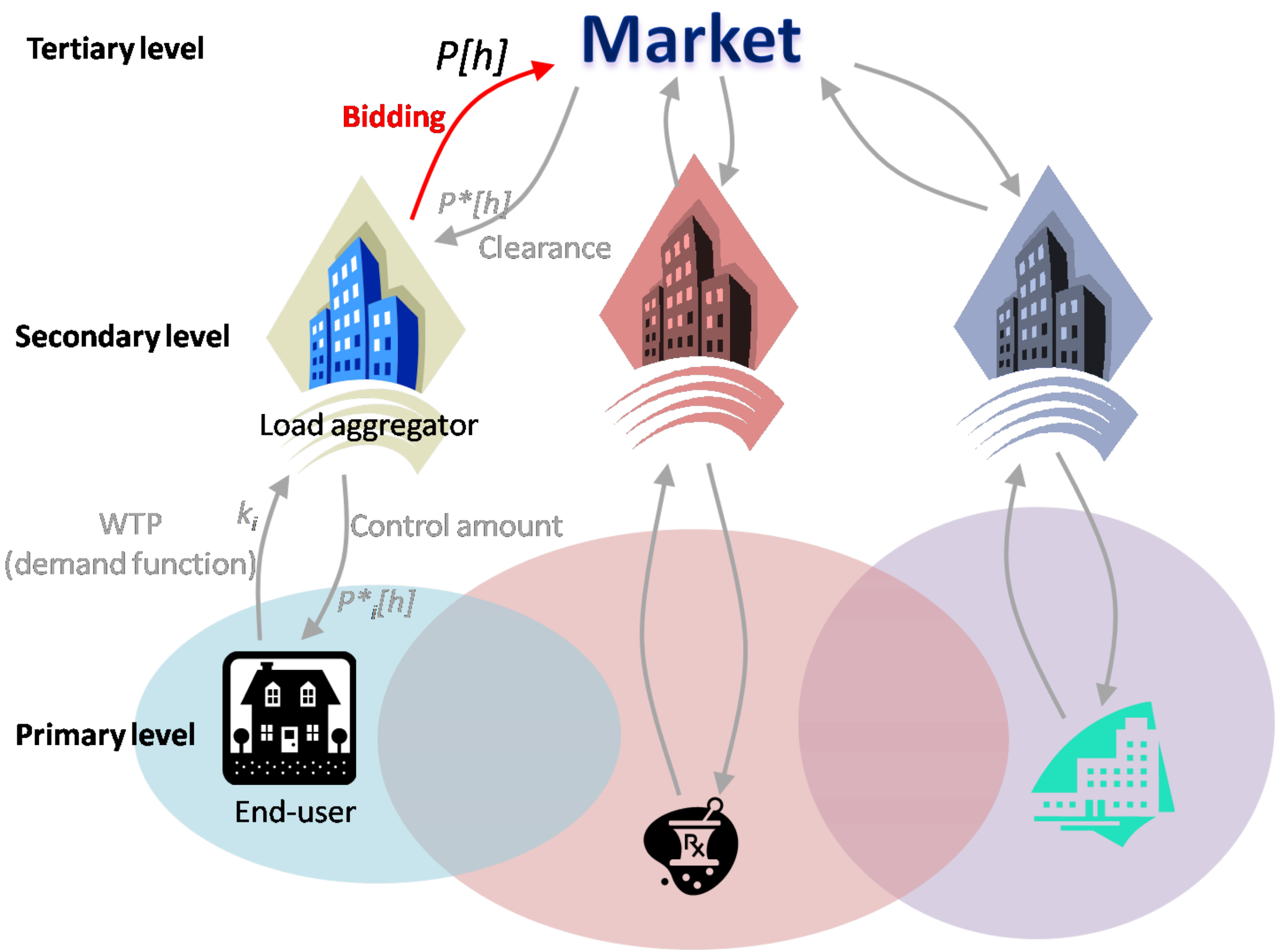
subject to $T_i^{\min} \le T_i[h] \le T_i^{\max}$ for all h

- Obtain different $P_i[h]$ s for different $\hat{\rho}[h]$s to infer k_i

→ Analogous to sensitivity analysis



Multi-layered adaptive load management – LAs to market



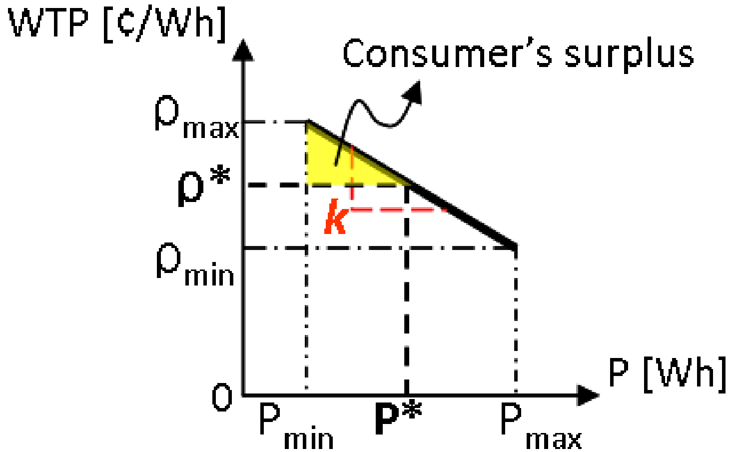
Multi-layered adaptive load management– LAs to market

- Optimizing individual power usage based on end-user's WTP

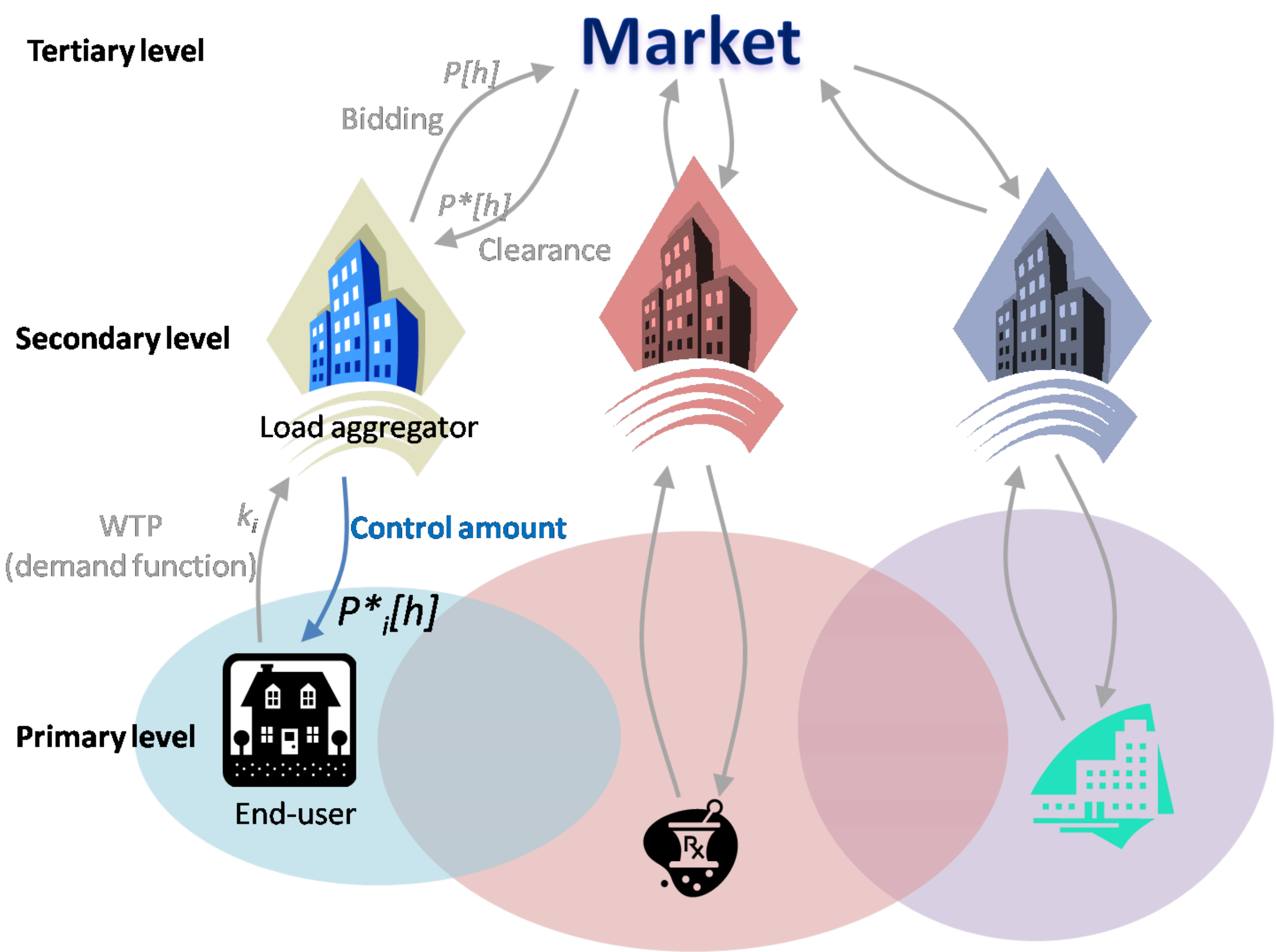
$$\min_{P_i(t)} \sum_{i=1}^{N} \sum_{t=t_0}^{t_f} \left\{ \left(\rho(t) - r_n(t) \right) P_i(t) - \left(P_i(t) + P_{i,\min} \right) \left(\rho_{i,\max} - \rho(t) \right) \right\}$$

subject to $P_{i,\min} \le P_i(t) \le P_{i,\max}$ for all i, t

- Variations possible depending on different end-user rates/pricings



Multi-layered adaptive load management – LAs to end-users



Multi-layered adaptive load management– LAs to end-users

- Optimizing real-time power consumption subject to energy control amount over an hour-interval given from load aggregator

$$\min_{P_i(t)} \sum_{t=t_0}^{t_0+12} \left[r_n(t) \sum_{i=1}^{N} P_i(t) - \sum_{i=1}^{N} \left(P_i(t) + P_{i,\min}\right)\left(\rho_{i,\max} - \rho(t)\right) \right]$$

subject to $\sum_{t=t_0}^{t_0+12} P_i(t) \le P_i^*$ for all i, t

Conclusion

- Load adaptive management
  - Two-way demand-side management
  - Multi-layered decision making process
  - Including end-users' individual economic preferences

Thank you!

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