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Self-Organising Algorithms for Residential Demand Response

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Smart Grid

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- Multi actor/objective
- Dynamic, non-stationary
- Heterogeneous
- Large scale

Irish Targets

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- Level of renewables in the power system to 40% by 2020. 17% in 2012
- 46 days above this instantaneously
- Best single day 2012 39% wind energy
- Wind curtailment 2.2% in 2011, 2.1% in 2012
- No more than 50% from non-synchronous generation

Residential Demand Response

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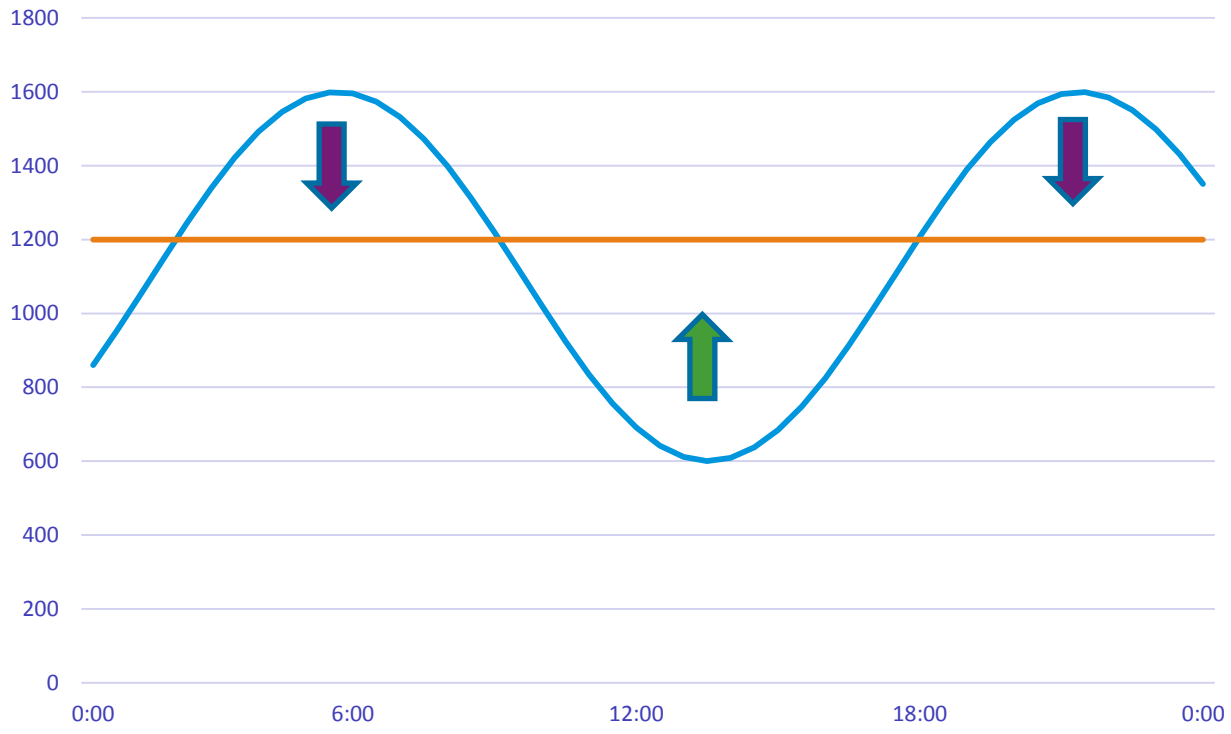

Algorithm Requirements

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- Multiple devices and objectives
- Allow for complex models
- Distributed control
- Three types
  - Probabilistic
  - Learning/Planning
  - Scheduling

Probabilistic

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- Two set point algorithms to control flexible load
- Variable charging rate
  - Uses an EV charger that can vary its power (0-100%)
  - The transformer broadcasts the charging rate (0-100%) that each of the available EVs should charge at.
  - The feedback is the measured aggregate power demand at the transformer.

Probabilistic

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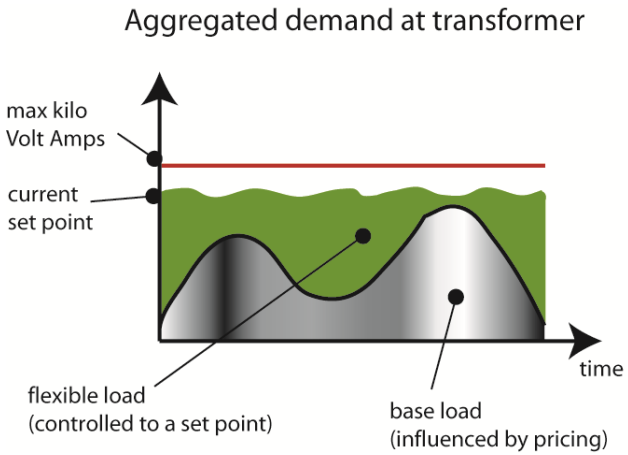
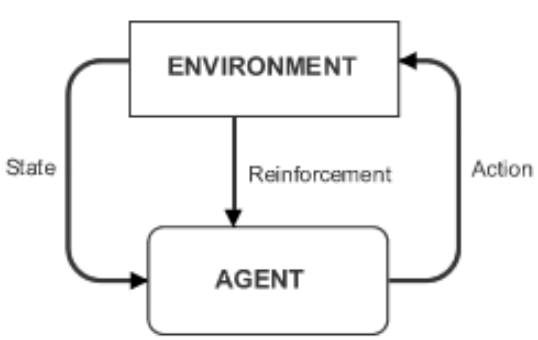
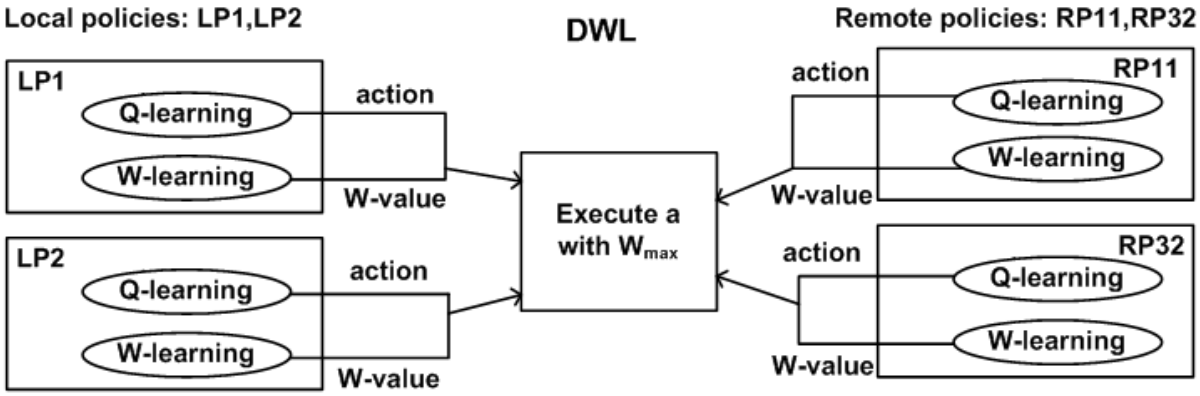


- Variable connection rate
  - Uses a much simpler on-off type of charger
  - The transformer broadcasts the connection rate (0-100% probability) that each of the available EVs should attempt to connect at.
  - The feedback is the measured aggregate power demand at the transformer.

Learning/Planning

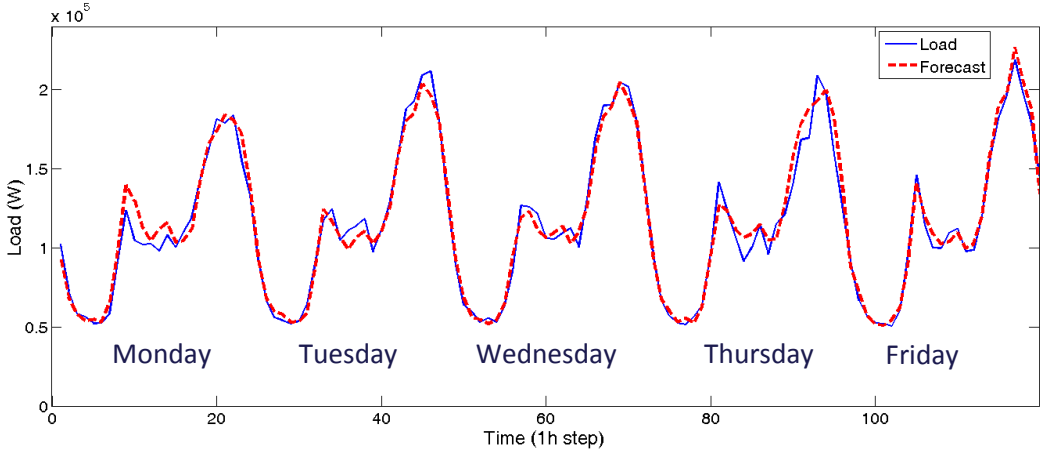
- Uses reinforcement learning
- Distributed W-Learning (DWL)
  - Multiple policies on each agents
  - Multiple agents collaborating
  - Learn dependencies between neighbouring agents
- Each agent learns how its actions affect its neighbours





Learning/Planning

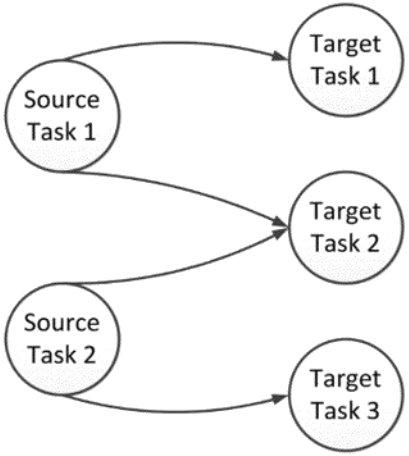
- Normal days prediction:
  - Combines several techniques with various advantages (ANN, WNN, ARIMA, NF)
  - Small scale prediction of load
  - Uses historical weather information from Dublin airport station
  - Achieves 2.39% NRMSE (evaluation over 20 consec. days)



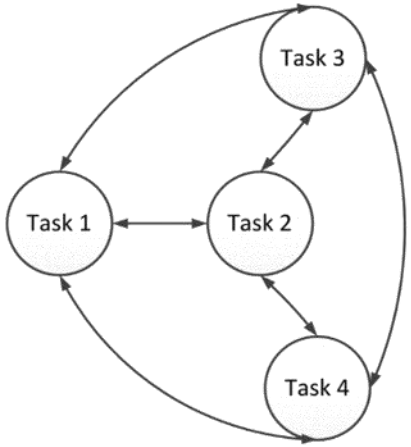
Learning/Planning

- Parallel Transfer Learning is an on-line version of Transfer Learning
  - Source and target tasks learn simultaneously, sharing information whenever they deem it necessary
- This allows the relatedness of tasks to be exploited
- Multiple transfers allow dynamicity of inter-policy relationships to be shared

Transfer Learning



Parallel Transfer Learning



Scheduling

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Evolutionary Algorithms are search methods that take their inspiration from natural selection and survival of the fittest in the biological world.

1: Randomly create an *initial population* of individuals (a.k.a. candidate solutions).

2: **repeat**

3: *Execute* each individual and ascertain its fitness.

4: *Select* one or two individuals from the population with a probability based on fitness to participate in genetic operations.

5: Create new individuals by applying *genetic operations* with specified probabilities.

6: **until** an acceptable solution is found or some other stopping condition is met (e.g., a maximum number of generations is reached).

7: **return** the best-so-far individual.

Scenario

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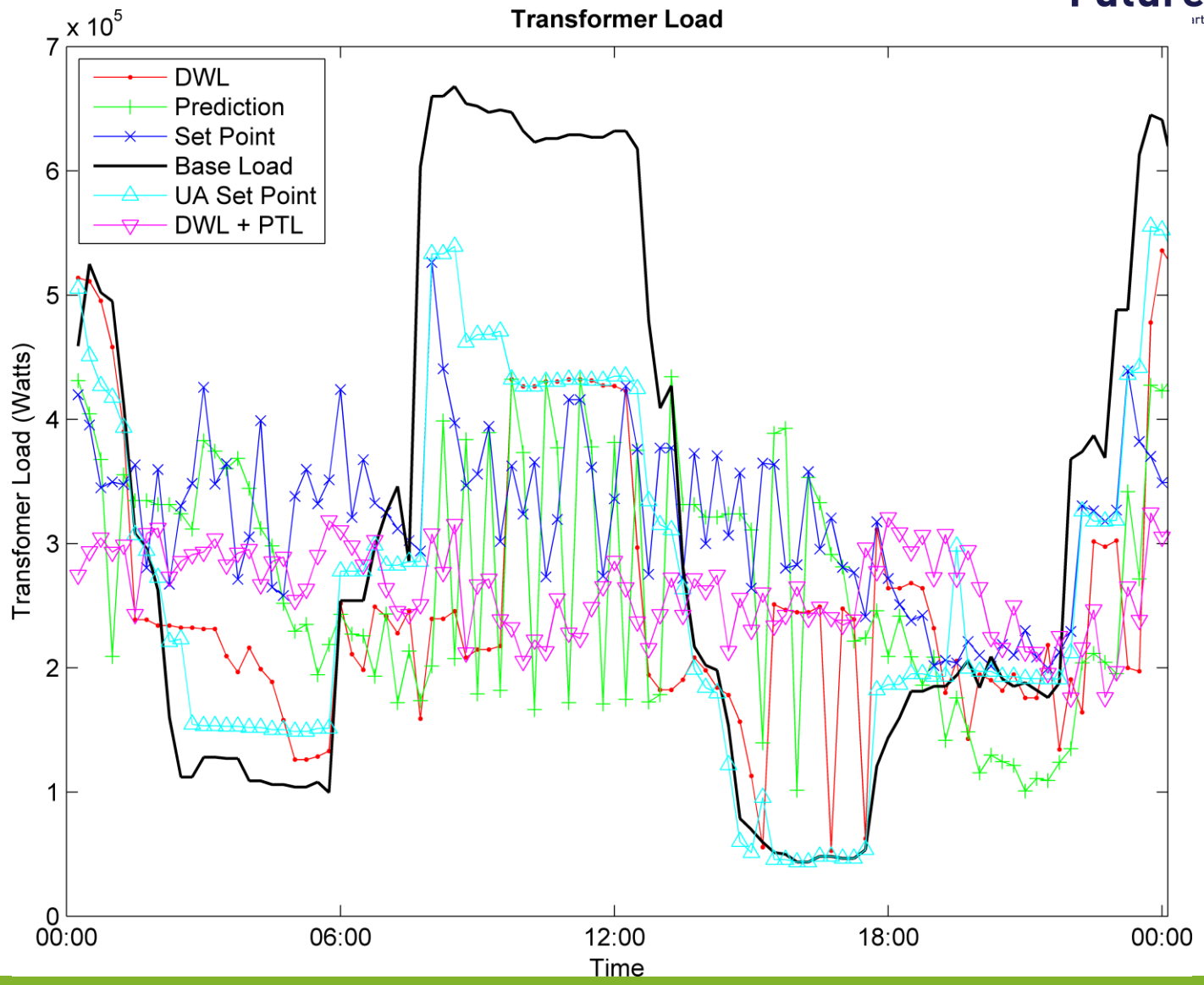
- 90 houses – EV (available 15 hours require ~6.4 hours charging), water heater (4.5kw) and base load
- 1 year long for seasonal variation

Results


Transformer Load
x 10^5
Transfomer Load (Watts)
Time
DWL
Prediction
Set Point
Base Load
UA Set Point
DWL + PTL
0
1
2
3
4
5
6
7
00:00
06:00
12:00
18:00
00:00

Results

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Method	Ave. Water Temperature	Ave. State of Charge	δ(kW)	PAR
Base Line	45.02°C	81.5%	1.934	2.13
DWL	52.74°C	39.71%	3.9162	2.12
DWL + Prediction	54.05°C	10.43%	7.2869	1.63
DWL + PTL	52.32°C	24.5%	2.5799	1.24
Set Point	60.74°C	43.71%	4.8198	1.65
User Aware Set Point	51.74°C	44.98%	2.3114	2.07

Future Work

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- More algorithms particularly centralized (scheduling) and competitive approaches
- Greater scale testing
- Tweaking of algorithms

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Questions?

Thank you.