Efficient Energy Trading Based on Blockchain Technology

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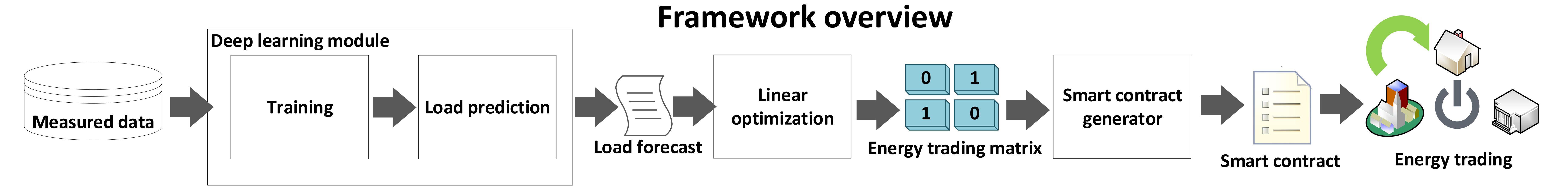
Abstract - In this paper, we propose a framework for efficient energy trading within the Smart Grid. Backbone of the system is smart contract generator supported by blockchain technology. System also features load forecasting model based on deep learning and a linear model for optimal energy distribution.

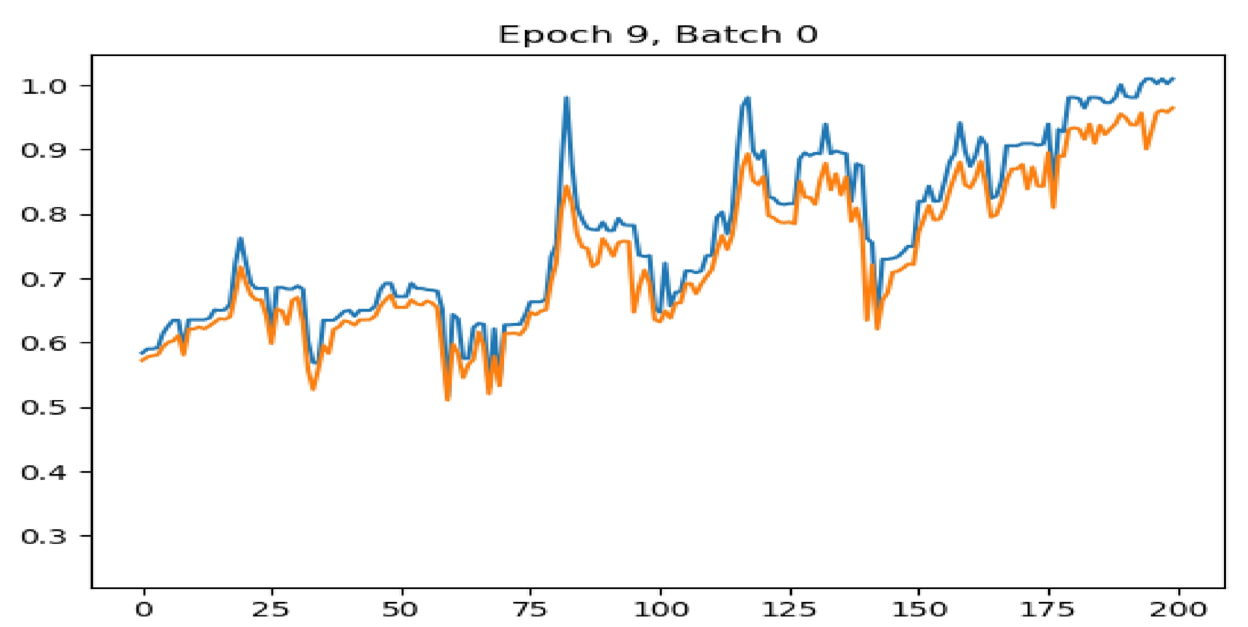
Framework overview



Load forecasting based on deep learning

Data set

Grid	Day	Rainfall [mm/m^2]	Temp [°C]	Consumption [MW]



TensorFlow
Python

Linear optimization AMPL model

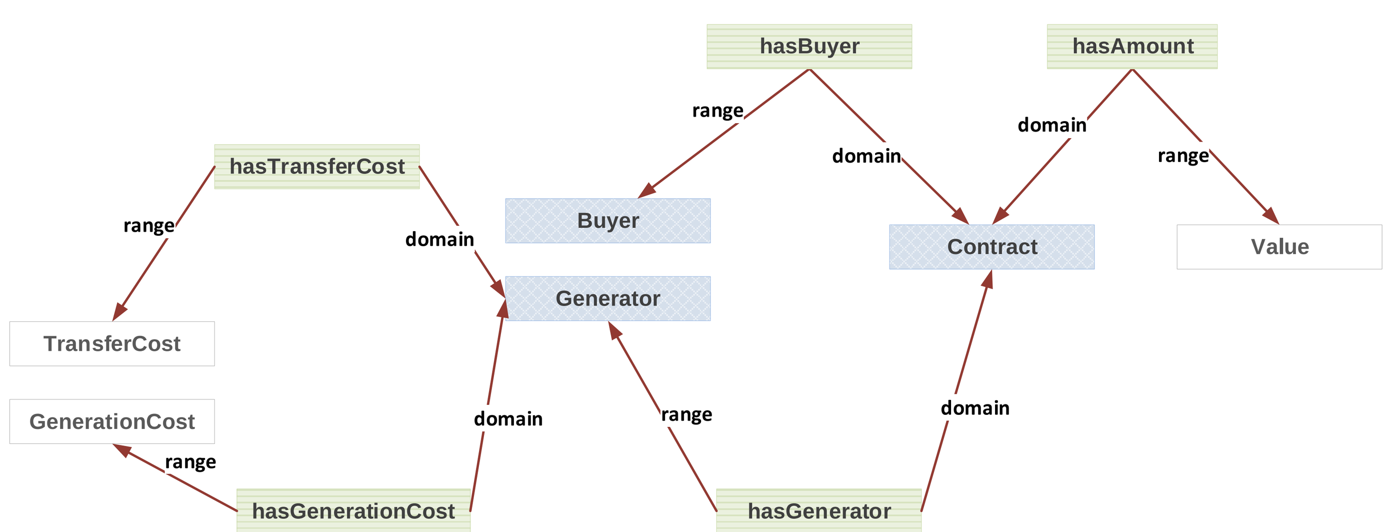
```
param numGrids;
set Grids:=1..numGrids;
param Transfer_Cost {i in Grids, j in Grids};
param Capacity {i in Grids};
param Demand {i in Grids};
param Generation_Cost {i in Grids};

# variable declaration
var X {i in Grids, j in Grids} >= 0;

# objective function
minimize cost:
       sum{i in Grids, j in Grids}
X[i,j]*Transfer_Cost[i,j]*Generation_Cost[j];

# constraints
subject to demand_satisfaction {i in Grids}:
      Capacity[i]+sum{j in Grids}(X[i,j]-X[j,i])>=Demand[i];
```

Semantic smart contract representation



Solidity smart contract for Ethereum blockchain

```
pragma solidity ^0.4.21;
contract EnergyTrade{
      event Sent(address buyer, address generator, uint amount, uint
transfer_cost, uint generation_cost);
      uint price;
      uint token_price;
      function trade() public {
      price=(amount*transfer_cost*generation_cost)/token_price;
            if (balances[buyer] < price) return;
            balances[buyer] -= price;
            balances[generator] += price;
            emit Sent(buyer, generator, amount, transfer_cost, generation_cost);
      }
}
```

Evaluation and results

Load forecasting

Training set size	Test set size	MRE [%]	Execution time [s]
75	25	11.08	0.39
750	250	8.02	0.57

Smart contract generation

N_g	N	T_{opt} [s]	T_{rdf} [s]	T_{sparql} [s]	T_{gen} [s]	T_{tot} [s]
5	1	0.19	1.16	0.72	0.28	2.74
8	5	0.23	2.16	1.18	0.63	4.21
10	8	0.27	2.92	1.32	0.91	5.48

According to the achieved results, the approach seems promising. The demand response was about 7% faster in the case when load forecasting was adopted. Load forecast had similar performance with slight improvements compared to previous work [15]. However, there are still many aspects to be considered in future. First, our plan is to work on integration of the presented framework with our existing IoT-based architecture for adaptive smart grids presented in [15, 27]. Once integrated, our goal will be to reduce the execution time of overall smart contract generation process in order to enable energy trading in real time. Moreover, another direction in our future work will be the adoption of blockchain technology to tackle the security issues in smart grids and smart contract verification.