Efficient Inference of Spatial and Temporal Conditions of Large Distributed Networks

Tiffany Tuor (Imperial), **Shiqiang Wang** (IBM US), **Kin K. Leung** (Imperial), **Bong Jun Ko** (IBM US)

Motivation

For a very large network with huge volume of time-varying data collected at thousands of distributed nodes, how to efficiently infer spatial and temporal conditions of the whole network?

Our Proposed Approach

- Each node decides when to forward locally collected data to a centralized controller, subject to limited communication bandwidth
- The controller groups nodes into clusters dynamically based on supplied data, and derives a compressed representation of the whole network, which can infer conditions of unobserved nodes (Spatial Prediction)
- Use the compressed representation to predict future behavior of the network (Temporal Prediction)

Spatial Predictions

- Use mean values of B clusters of nodes to represent conditions of unobserved nodes
- Each node sends updated data to the controller when it expects a change of its cluster membership, inspired by Lyapunov optimization, subject to bandwidth constraint

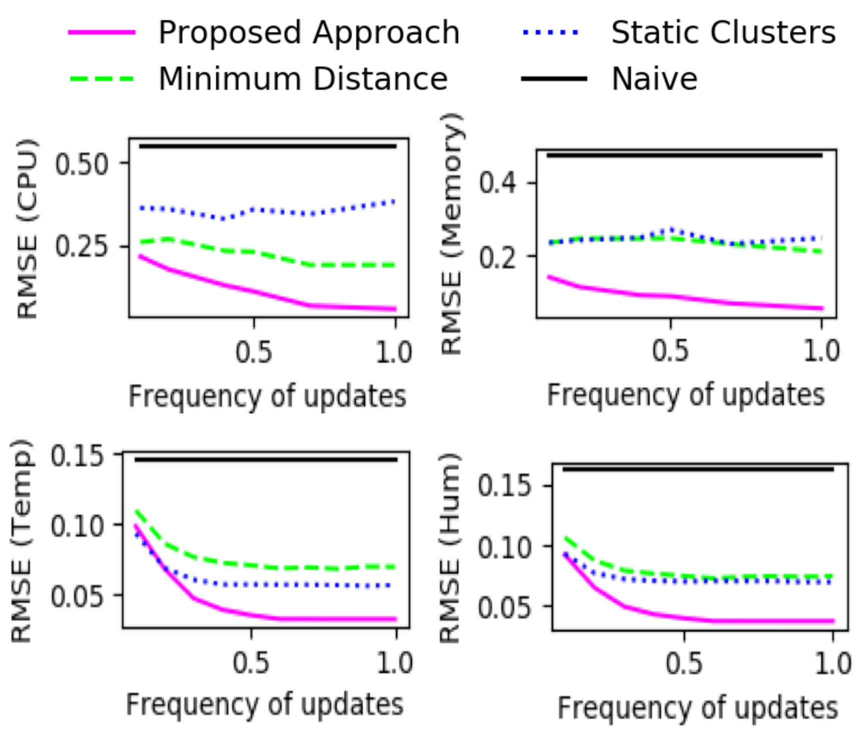
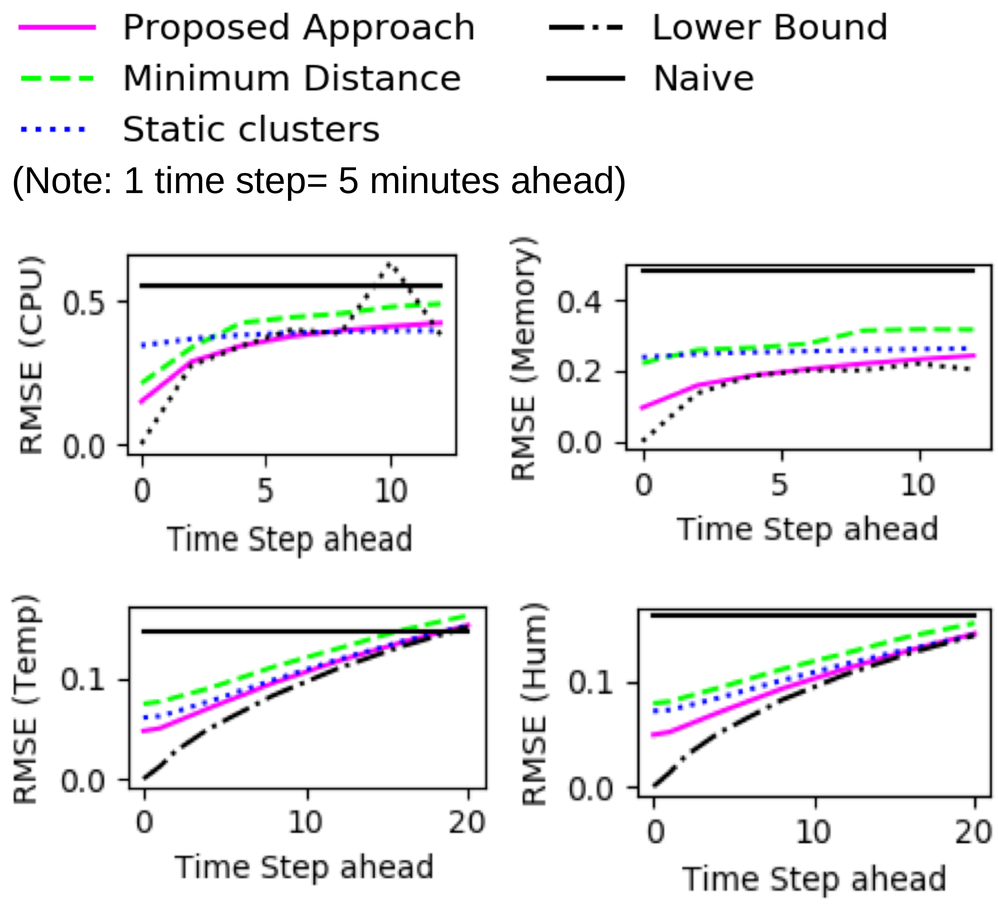


Figure 1: *Spatial prediction.*
<u>Top:</u> CPU & memory usage of 100 machines, B = 10.
<u>Bottom:</u> temperature & humidity of 47 sensors, B = 3.

Spatial & Temporal Predictions

- Best but non-scalable approach: One forecasting model for each node with its root mean square error (RMSE) as lower bound for our proposed approach
- Our Proposed Approach: Use a forecasting model for each of B clusters and consider temporal correlation to identify the best forecasting model for a given node



(Note: 1 time step= 5 minutes ahead)

Figure 2: *Spatial & temporal prediction at different steps ahead (freq. of updates = 0.3).*
<u>Top:</u> CPU & memory usage of 100 machines, using 10 forecasting models (B = 10).
<u>Bottom:</u> 47 temperature & humidity sensors using 3 forecasting models (B = 3).

Comparison with Two Other Approaches:

1. Spatial predictions using data from B randomly chosen nodes. An unobserved node is treated as one of the B nodes based on minimum distance (Minimum Distance)
2. Predictions by data averaged across nodes of static clusters (Static Clusters)

Note: Our proposed approach is similar to Approach 2, but with dynamic clustering.

Distributed Analytics and Information Science International Technology Alliance
Annual Fall Meeting, September 2017