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Deep Learning for Estimating Sleeping Sensor's Values in Sustainable IoT Applications

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***Abstract*—The aim of this work is to develop a deep learning model that uses spatial correlation to enable turning turn off a subset of sensors while predicting their readings. This considerably saves the energy that would be consumed by those sensors both for sensing and communications (reporting the reading to the central station), which prolongs sensors' lifetime and opens sky for a plethora of Internet of Things (IoT) applications. Subject of this research, event-based sensing is more challenging than periodic sensing and is uncovered in the literature. We explore advanced learning approaches including Graph Convolutional Network (GCN) and Generative Adversarial Networks (GANs) and comb them in a novel way to derive a solution that uses both spatial correlation and the readings of the active sensors to accurately generate the missing readings from inactive sensors. The proposed solution is holistic and does not rely on any duty-cycling scheduling policy. A generic random pattern is used in this paper in which every sensor is duty-cycled randomly. The structure of the network is plugged into the GCN through a graph derived using the sensing range, as well as the euclidean distance between the sensors that determines the wights on the edges. Moreover, the accuracy of the GCN is enhanced by optmizing the weights of its deep neural network with a GANs and a game theory based model, which adversarially trains the GCN's generator by estimating the generator's performance and calculating the Wasserstein distance between the real and the generated data. The proposed solution is evaluated in comparison with the most relevant state-of-the-art approaches in terms of accuracy, energy consumption. The results show that the proposed solution provides high performance and is clearly superior to all the compared solutions in terms of reducing energy consumption and improving accuracy.**

***Keywords*—IoT, wireless sensor network, Deep Neural networks, adversarial training, graph convolutional networks, sensor energy saving.**

I. Introduction

Preserving batteries of low-power devices, such as wireless sensors, is a key solution for achieving sustainable Internet of Things (IoT). This will not only enable an abundance of applications that will benefit our society and economy but will significantly contribute towards green computing by reducing battery disposal and preserving the environment. However, today's real-world applications face a big challenge in achieving long term deployment without battery replacement. Many research efforts have been devoted to the design of power-management policies and protocols, e.g., duty-cycling scheduling [1], medium access protocols [2], routing protocols [3], optimal relay node placement [4], etc. These solutions contribute in prolonging batteries life-time but remain insufficient and are reaching their limits. Other trends focused on the energy harvesting from the environmental resources such as electromagnetic waves (wireless charging), solar, wind, etc., and proposed solutions to design appropriate hardware [5], as well as adaptive models and protocols, e.g., [6], [7]. All this helps prolonging the lifetime but remains insufficient given the instability and variability of the ambient resources. This problem is addressed herein by taking advantage of spatial correlation between sensors and exploring advanced machine learning methods to accurately estimate sensorial data readings when sensors are turned off. This way, the sensors can be kept off as long as possible while using the model to generate the missing data.

We focus on event-based applications that were uncovered in the literature from this perspective. Although optimal sensing coverage is often required for various applications, continuous monitoring of the entire field is not always needed for detecting events that occur during short periods and can be detected by more than one sensor. As the position of a sensor impacts its reading, several sensors may detect the same event when nodes' sensing fields overlap. Therefore, sensors can mutually cover missing detections of one another if they are correlated to the event. For example, in a commercial building application motion sensors in certain areas reporting the arrival of employees are generally sequentially related. By creating a model capable of learning data correlation, the sensors' values will be predicted and the energy that those sensors would consume for sensing and communications (transmission of their reading to central stations) will be saved. Two approaches may be considered to reach this target, 1) turning "off" all the sensors simultaneously then exploiting temporal correlations to predict future values from their last readings, 2) turning part of the network "on" and using spatial correlations to deduce the values of the sleeping sensors. We already explored the first approach in [8] and used a sequence model based on LSTM