I. INTRODUCTION

The Structural Health Monitoring system, if implemented, is very key in the process of identification of the bridges' deformations resulting from environmental factors and heavy vehicle loads. The American Society of Civil Engineers statistics showed that in 2021, about 7.5% of all bridges in the United States had structural deficiency, presenting risks to both the public and safety and economic stability. Traditional inspection techniques, such as visual, are time-consuming, prone to error, and are often unable to find early-stage damage that can result in catastrophic failures. SHM offers a possibility for early indication of bridge damage, thus ensuring safety at lower costs during maintenance[1]. SHM systems implemented using Wireless Sensor Network (WSN) are gaining usage since it can supply users with real-time data, it is cost effective, provides accurate, reliable and healthier information[2][3]. The recent development of IoT-based WSN technologies has further improved their application value in structural health monitoring by realizing the fusion of various sensors and data aggregation ways[4]. In WSN-based SHM, the sensors are the basic instruments to measure and acquire data related to structural responses[5]. Any individual sensor remains valid to the application so long as its battery stores adequate charge enough to power on the sensor[6]. Another form of the sensor, which is quite popular, is the accelerometer sensor, which is in wide use in measuring vibration analysis of bridges.

Accelerometer sensors in WSNs were proved to detect changes of the vibration frequency induced by external loads or environmental conditions[5]. Such frequency is a fundamental index of the health of bridge structure. Moreover, accelerometer-based WSNs proved also effective in measuring dynamic responses such as vibration frequencies, which are a fundamental indicator of the structural health[7]. In fact, a significant variation of the vibration modes will usually become the forerunner of damage for a bridge component. Still, one of the major problems is how to process the raw information from the sensor so that it is possible to obtain useful and meaningful information, including the detection of the damage and its exact location, as the importance of calibration underlines in many studies for accelerometer sensors in order to have accurate data acquisition for detecting structural changes under various conditions of load[8].

The rising of machine learning technology, especially neural networks, becomes a potential answer for this problem. Neural network was proved to be able to detect and localize damage with high accuracy even under complex environmental conditions[9]. Neural networks have the capability to learn from data without any process of feature design[10]. In various researches, neural networks have shown great ability in the area of pattern recognition and classification for complex data with high accuracy[11]. In addition, neural networks can handle large-size data, including vibration signals, images, or time-frequency representations, without relying on sophisticated physics-based models[12]. This reduces manual generation of features and increases efficiency in the damage assessment process to a great extent. It can also be used to perform further vibration frequency data analysis obtained from accelerometer sensors for damage detection and location with a high degree of accuracy.

The research will focus on developing an optimized Artificial Neural Network (ANN) architecture to address the gaps in current SHM systems by developing an optimized ANN architecture integrated with WSNs. By leveraging natural frequency data captured by accelerometer sensors, the proposed system ensures real-time, automated, and cost-effective structural health assessments, providing a reliable solution for safer and more efficient bridge management. Integration of ANN algorithms with accelerometer frequency analysis has been a great stride in damage detection and localization for safer and more efficient bridge management.