# Networkless Wireless Sensing for Bridge Structural Health Monitor (SHM)

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## Abstract

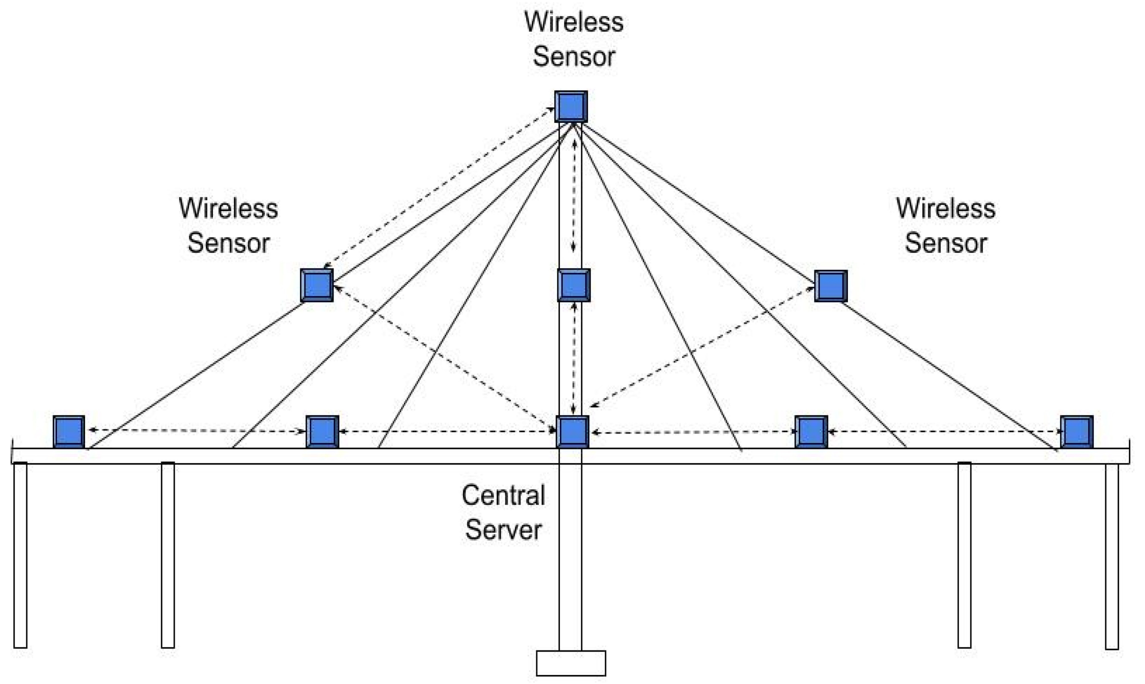
The American Society of Civil Engineers (ASCE) publishes a report card on the nation's infrastructure every four years. The most recent one in 2019 gave the nation's bridges an unimpressive C grade, Across the country, there are more than 617,000 highway bridges; 46,154 or 7.5% of them are deemed structurally deficient, and 42% of them are at least 50 years old. This means that continuous condition assessment of these bridges is essential for protecting the safety of the public. According to the requirement set by Federal Highway Administration (FHWA), all highway bridges must be inspected at least once every 24 months. Meeting this 24-month inspection period for all highway bridges is a challenging task if time-consuming, labor-intensive inspection techniques are employed. To address this issue, civil engineers have been using bridge health monitoring (BHM) systems using wired and/or wireless sensors to measure the structural response of bridges. These response measurements are then converted to information related to structural health/condition for assessment.

## Problem Statement

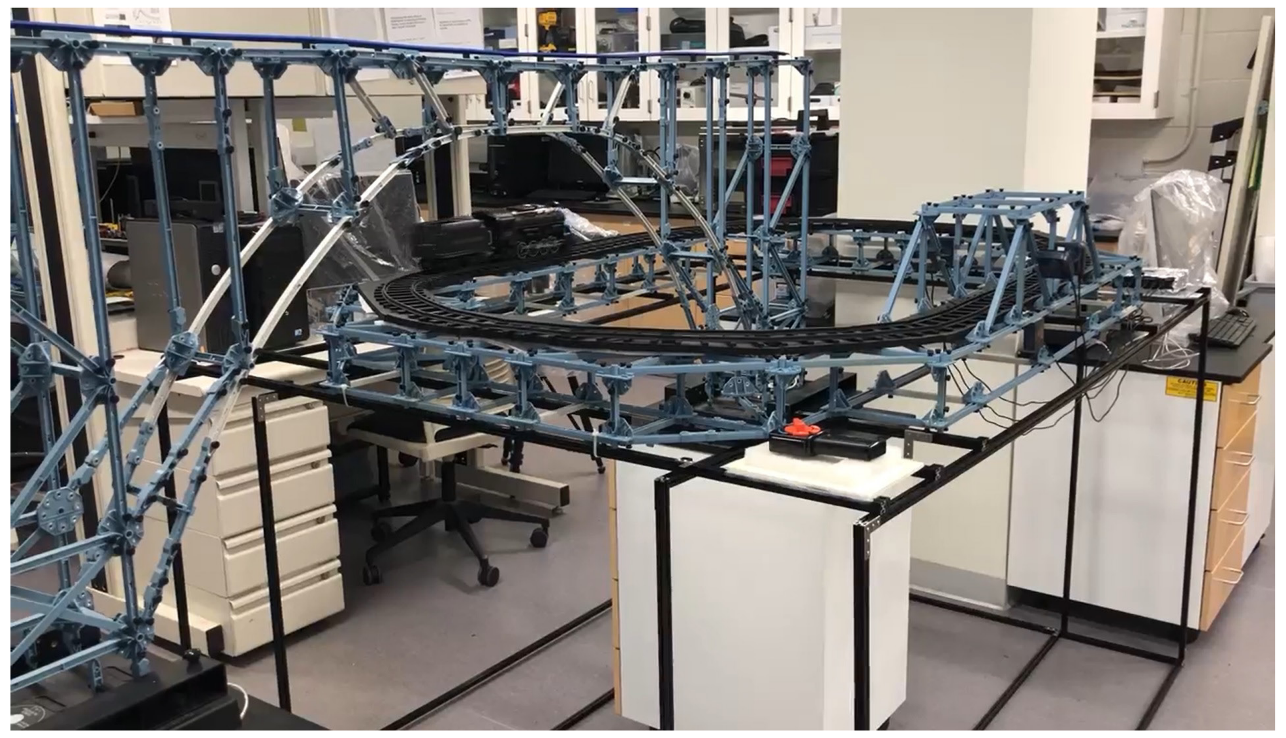
The state-of-the-art technology in Structural Health Monitoring (SHM) deploys sensor networks to facilitate data connection. The future of SHM must be wireless. Installing cables is expensive and subject to extreme weather. Wireless solutions face challenges such as energy consumption. Each little sensor placed throughout the bridge is battery-powered. Like how it works on your phone, sending information through wi-fi or a cellular network consumes energy. The batteries would have to be made to operate for the longest time on a single charge. Another not well-publicized problem is security threats. There are two types of attacks on a system, those being Active, or Passive attacks. In active attacks, the most common are Denial of Service (DoS) and Jamming. For passive attacks, there are eavesdropping and monitoring attacks. For example, jamming attacks occur when a single node in the WSN is confiscated and jams the transmission inside the network.

## State of the Art

SHM with WSNs has been researched only recently. There have been many different trials and errors that have come along with the different types of topologies that fit best with the Bridges demands. A team of researchers studied several types of topologies [2] and found in a traditional WSN the Hierarchical Cluster-Based Topology was the most efficient, as its primarily decentralized and does not bottleneck the sensor node closest to the central server. A traditional topology is depicted below to represent a bridge contour.




## Our Approach

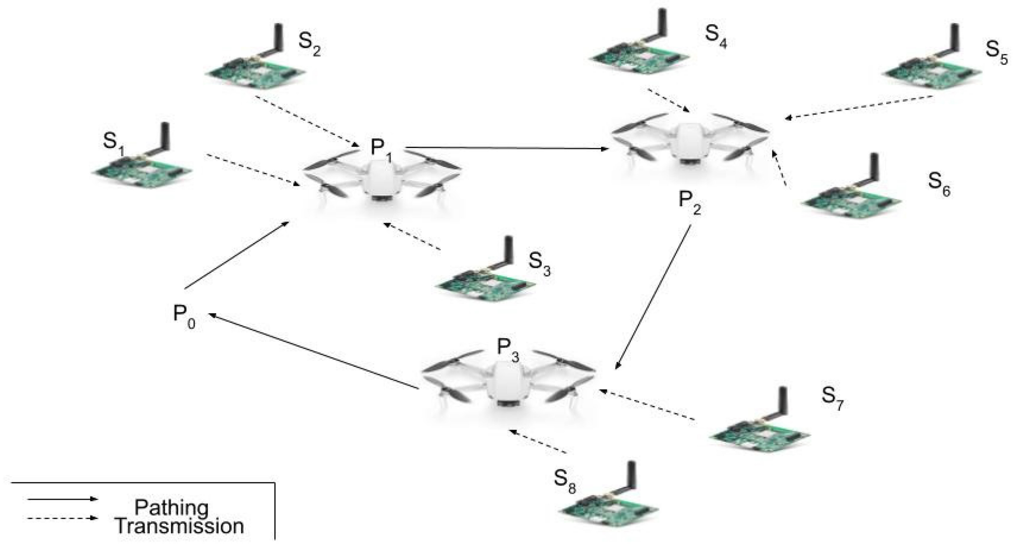


Our approach to wireless BHM is to utilize sensors networkless by collecting data with a drone. Similar to a mail carrier who goes around and picks up the mail, a drone collects data from sensors throughout the bridge. A drone eliminates restrictions on civil engineers about node placement since the drone replaces sink nodes, relaxing topology constraints.

Another advantage of networkless makes BHM not prone to attacks such as Jamming and DoS. To secure access, we deploy a Needham-Schroeder authentication protocol that will allow the drone to collect the data from all sensor nodes securely.

## Challenges

One challenge this research comes across is the drone pathing for data transmission. Whether that be hovering vs moving. A group of researchers [1] conducted a study and found that the most time efficient method was when the drone was hovering. In doing this, each hovering point has a subset of sensor nodes that will send data to the drone when it is hovering over this point. The drone must follow the sequence and hover over each hovering point for data gathering, as depicted below.




## Conclusion

The implementation of networkless sensing for BHM considers energy efficiency. This system saves battery life as the sensor nodes remain asleep until either scheduled transmission or woken up by a drone. Networkless allows a simpler sensor node, only one-way communication (to the drone) which reduces design complexity and operation energy. The system also assures security since there is no vulnerable network to be attacked.

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### Acknowledgement

This work is partially sponsored by the National Center of Academic Excellence in Cyber Defense Research (CAE-R) at the University of Massachusetts Dartmouth, summer 2022, and NSF-IGE 2105718.

**2022 IEEE MIT Undergraduate Research Technology Conference (URTC)**
September 30 to October 2, 2022

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