別紙４－１（課程博士（英文））

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Abstract (Doctor)

Title of Thesis	TenSense – A Family of Wireless Sensor Nodes Dedicated for Remote Unattended Structural Health Monitoring of Bolted Joints

Approx. 800 words

The advancements in technology, manufacturing and communication disciplines have created new research opportunities in major scientific fields. Interaction between the fields started to blur the lines between them giving birth to new areas such as Internet of Things (IoT). IoT spans multiple disciplines including but not limited to Electronics Engineering, Computer Science, Mechanical Engineering, Civil Engineering, etc. It is a multidisciplinary field that drives the development and integration of smart connected things into every sector of our living and working environments. IoT applications vary greatly in nature, however, the majority of them are targeted at some sort of automation, control or sensing enabled by smart things. A group of those things are categorized as smart sensors which are used for smart metering, agriculture, asset tracking, etc. An area where IoT can make a huge impact is Structural Health Monitoring (SHM). Currently the maintenance of the structures is done on an ad hoc or scheduled basis. However, by leveraging the sensor data being constantly gathered and assessed, this process can be made more dynamic and enable to recognize the structural fault before it develops, propagates and results in irreversible damage. This particular research, therefore, concentrates on the application of predictive or pre-emptive maintenance of large stainless material constructions, e.g. bridges, windmills, etc. Current approaches towards SHM are analyzed, and a research gap is identified. To fill this gap, a pair of specialized smart sensor nodes codenamed TenSense are designed and evaluated for the purpose of monitoring the pre-tension load of bolted joint connections in these stainless structures. Both nodes have different shapes, and provide different mounting approaches, resulting in a degree of flexibility for every use case. The main functionality, however, remains the same. Both nodes feature Long Range (LoRa) wireless communication for data transmission and employ the same sensing approach. Full node designs are provided, and every aspect behind the approach and decisions are justified by research, comparison, and simulations undertaken. Design includes a Mechanical stage, wherein a custom shape

TenSense node is created, and Electronics stage, wherein a schematic, Printed Circuit Board (PCB) layouts, and embedded firmware are created. These two components are then fused together to create TenSense. The resultant design is thoroughly evaluated employing physical means. Public blockchain is utilized for secure, decentralized, and transparent data storage that enables Smart City services to access and use the SHM data for its purposes. LoRa communication protocol improvement is proposed, and finally TenSense nodes are compared to the State-of-the-Art solutions further solidifying the novelty of the approach. Results show that TenSense is able to precisely track the bolts preload, with a maximum deviation of 2% from the reference, and the design is safe under the maximum preload. Communication distance was measured to be 3.8 km from the base station and the node is estimated to last over 5 years.