Wireless Sensor Network for Slope Monitoring

Project Code: MWRS2-08

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Landslides are natural geographical hazards and every year in Hong Kong great losses of life and property are caused by landslides. Although there has been no known way to prevent this type of accidents from happening, proper monitoring of slope conditions and accurate forecast of landslides can greatly reduce losses. Therefore slope monitoring is crucially important at places where landslides are likely to happen in order to reduce and prevent such losses.

The aim of this project is to prepare a wireless sensor network (WSN) based system for slope monitoring applications. There are several reasons for choosing wireless sensor network: 1) a typical application for WSNs is structural monitoring, 2) it is cheap yet reliable and 3) it greatly reduces manpower compared to traditional methods.

System Block Diagram

Fig. 1 shows the system for the whole Hong Kong area where each subsystem represents a single slope or several adjacent slopes.

Fig. 2 shows a typical subsystem. The root node represents the base station which gathers all information and has with wireless internet communication capability. The cluster heads (CHs) gather information from their corresponding sensor nodes and pass the information back to the base station for further processing. The leaf nodes represent the sensor nodes which can take required measurements and send the information back to their corresponding cluster heads. Note that as in Fig. 5 the topology is in a dynamic nature; however, in the final proposal, the topology is a mesh network which, for example, means that there may also be a link between CH1,2 and CH2,3 in Fig. 2.

Another point is that all links represented in the above two figures are realized using wireless communication technology.

Description of the Proposed Solution

• The proposal utilizes the IEEE 802.15.4 and Zigbee standard standards which define all layers of the sensor network. The work of this project mainly focuses on building an efficient topology control algorithm.

• There are two types of nodes in the network: full-function devices (FFDs) and reduced-function devices (RFDs). For this specific application, FFDs act as base station (BS) and cluster heads (CHs).

• PHY layer: 2.4 GHz wireless communication range, supports IEEE 802.15.4 and Zigbee.

• MAC layer: supports both, basic and enhanced CSMA/CA, Carrier Sense Multiple Access - Collision Avoidance (CSMA-CA).

• Data aggregation: every FFD needs to perform simple data analysis tasks to determine whether to update information in the base station. This reduces the amount of information to be transferred.

• Topology: Frame-based full-duplex topology control algorithm (ESATC).

Before the detailed description of ESATC, there are several advantages for using this algorithm: 1) The standard gives the energy efficient solution with different MAC protocols; 2) Cost will be low by using HDLC; 3) It is easy to deploy; 4) It has a more efficient link aggregation method and 5) By using ESATC, the lifetime of the network is greatly prolonged.

The ESATC Algorithm

The aim of this algorithm is to prolong the lifetime of the network by dynamically varying the topology. There are four steps in this algorithm:

1. Link cost: Each link is evaluated using the following equation:

\[ C_{link} = d_{link} \times \left( \frac{P_{trans}}{P_{receiver}} \right)^{2} \]

Where, \( C_{link} \) is the cost of direct link between nodes \( i \) and \( j \); \( d_{link} \) is the minimum transmission power between \( i \) and \( j \); \( P_{trans} \) is the transmitted power per unit area in the transmission time, \( P_{receiver} \) and \( P_{trans} \) are the initial energy in a node. \( \alpha \) and \( \beta \) are sensitivity energy in nodes and link cost respectively.

2. Information collection: Consider any node \( i \) in the graph, the information that needs to be processed at node \( i \) is neighbors’ \( \{ j \} \). Every neighbor of \( i \) has a neighbor information table. The table includes node ID, MAC address, and current state of link.

3. Topology Construction: Based on the obtained neighbor’s information, we construct a complete information graph. Then, the topology is constructed as the shortest path tree from BS to each node and the network topology is optimized.

4. Transmission Power Adjustment: Node \( i \) transmits power periodically. Each time the transmission power is set to be the minimum power needed to cover all of its logical neighbors, i.e., \( i \) is within the transmission range of all logical neighbors.

Simulation Results for ESATC

• Typical Scenario

In this scenario, there are bottleneck nodes in the network, i.e., red nodes in Fig. 4. It shows the MAC layer graph. The other shows the topology of the network versus time.

Fig. 4 shows the average transmission power with respect to time. The link is prolonged compared to the red line, which is a static topology control algorithm used for comparison.

Fig. 5 shows the residual energy for five nodes in the network: (a) in the static algorithm and (b) is ESATC. We can see that ESATC has a longer life time in all nodes used and it is more efficient without sacrificing communication performance.

Random Scenario

In this scenario, all nodes uniformly distribute in a network area of 1000 x 1000 m2. Fig. 6 shows the life time of the network, and the average transmission power. Fig. 7 shows average signal and physical distance. Smaller distance generate less traffic at each node. The red line represents ESATC.

Conclusion and Suggestions on Future Work

In conclusion, the Final Year Thesis proposed a way to implement a wireless sensor network based system for slope monitoring applications. And the key innovation of this project is the new topology control algorithm. It exhibits significant improvement in lifetime of the network.

Since the algorithm does not require the use of a base station, future work could be done on solving the problem in a distributed manner based on this algorithm. Future work could also be done on actually implementing the system.