Abstract

Simultaneous sensor and actuator placement for identification and containment of contaminants in a water distribution network.

1 Scenario

1.1 Given

Specification of water distribution network – vulnerable nodes, demand nodes, the adjacency matrix.

Time-delay in sensors of contaminant sensing, etc. can be added onto this work without much hassle, and are ignored.

1.2 Requirements to be satisfied

To find distribution of sensors on nodes and actuators on edges such that the vulnerable node can be identified and the contaminant can be prevented from reaching the demands.

2 Previous work

Sensor placement using the principle that there must exist a unique non-zero set of sensors for each set of vulnerable nodes that can be affected.

Actuator placement on edges to achieve a balanced min-cut, between the sensor nodes and demands.

3 Hypotheses

Simultaneous sensor and actuator distribution can be achieved and is more efficient – these are dependant problems.

4 Method

We first develop an algorithm and formulation for each case, implement in MATLAB for cases, compare with results from previous work.

5 Implementation

Case 1: Shutting the network effectively stops the contaminant beyond the actuator too.

In this simpler case, there are no additional constraints on the actuator placement problem beyond the (balanced) min-cut of the entire graph.

As long as the sensor network can detect the contaminant before it reaches the demands and the actuation can happen simultaneously, the requirements are satisfied.

Case 2: The contaminant contained only in the vulnerable side of actuator network

This case is not trivial as the positions of the sensors must be used as input, i.e ensuring they are on the vulnerable side.

Formalism as binary integer optimization problem:

$$
\begin{array}{rcc}
min & (\sum x_i + \sum y_i + \sum z_i) & \\
sub & & \\
\mathbf{A}\begin{bmatrix} \mathbf{x} \\ \mathbf{y} \\ \mathbf{z} \end{bmatrix} & \geq & \mathbf{b} \\
\mathbf{A_{eq}}\begin{bmatrix} \mathbf{x} \\ \mathbf{y} \\ \mathbf{z} \end{bmatrix} & = & \mathbf{b_{eq}}
\end{array}
$$

Where x_i is 1 if there exists a sensor at i^{th}node, 0 otherwise.

y_i is 1 if i^{th}node is in the demands side of the actuators, 0 otherwise.

z_i is 1 if there exists an actuator at i^{th}edge, 0 otherwise.

After adding constraints from each of the sub-problems, the only thing left to do to enforce containment is to add constraints reflecting it. Our aim is to force whatever partitioning to happen in the region farther away from the contaminant than the sensor nodes. So we use shortest path lengths from all the vulnerable nodes (simulating an attack on all of them) to all the nodes in the graph to model "farther away". There are still problems associated with this approach, which I'm working on now.

For example, take the graph generated by *adjGraph = sparse([1 1 2 2 2 3 3 4 5],[2 3 4 5 3 4 5 6 6],[2 2 1 1 1 1 1 2 2],6,6);*

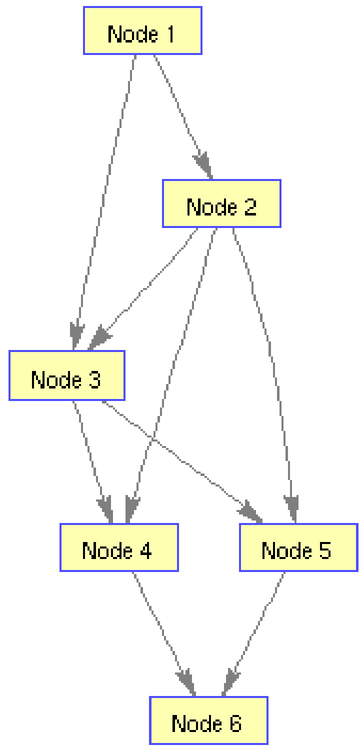

Figure 1: The test graph

I'm currently working on implementing this in MATLAB.

References

[1] V. Reddy, 2015 - Sensor network design for contaminant detection and identification in water distribution networks.

[2]