Distributed Cut Detection Algorithm

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Abstract

In this article we propose a Distributed algorithm to detect cuts, named the Distributed Cut Detection (DCD) Algorithm. The algorithm allows each node to detect DOS events and a subset of nodes to detect CCOS events. The algorithm we propose is distributed and synchronous: it involves only the local communication between the neighboring nodes and is robust to temporary communication failure between node pairs. A key component of the DCD algorithm is a distributed iterative computational step through which the nodes compute their electric potentials. The DOS detection part of the algorithm is applicable to arbitrary networks; a node only needs to communicate a scalar variable to its neighbors. The CCOS detection part of the algorithm is limited to networks that are deployed in Euclidean spaces, and nodes need to know their own positions.

1 Introduction

Wireless Networks are a promising technology for monitoring large regions at high spatial and temporal resolution. We consider the problem of detecting cuts by the nodes of a wireless network. We assume that there is a specifically designed node in the network, which we call the source node. The source node maybe a base station that serves as an interface between the network and its users. Since a cut may or may not separate a node from the source node, we distinguish between two outcomes of a cut for a particular node. When a node u is disconnected from the source, we say that a DOS (disconnected from source) event has occurred for u. When a cut occurs in the network that does not separate a node u from the source node, we say that a CCOS (connected, but a cut occurred somewhere) event has occurred for u.

2 Applications

Area monitoring
Area monitoring is a common application of WSNs. In area monitoring, the WSN is deployed over a region where some phenomenon is to be monitored. A military example is the use of sensors detect enemy intrusion; a civilian example is the geo-fencing of gas or oil pipelines.

**Health care monitoring**

The medical applications can be of two types: wearable and implanted. Wearable devices are used on the body surface of a human or just at close proximity of the user. The implantable medical devices are those that are inserted inside human body. There are many other applications too e.g. body position measurement and location of the person, overall monitoring of ill patients in hospitals and at homes.

**Environmental/Earth monitoring**

The term Environmental Sensor Networks has evolved to cover many applications of WSNs to earth science research. This includes sensing volcanoes, oceans, glaciers, forests, etc. Some of the major areas are listed below.

**Air quality monitoring**

The degree of pollution in the air has to be measured frequently in order to safeguard people and the environment from any kind of damages due to air pollution. In dangerous surroundings, real time monitoring of harmful gases is an important process because the weather can change rapidly changing key quality parameters.

**Interior monitoring**

Observing the gas levels at vulnerable areas needs the usage of high-end, sophisticated equipment, capable to satisfy industrial regulations. Wireless internal monitoring solutions facilitate keep tabs on large areas as well as ensure the precise gas concentration degree.

**Exterior monitoring**

External air quality monitoring needs the use of precise wireless sensors, rain wind resistant solutions as well as energy reaping methods to assure extensive liberty to machine that will likely have tough access.

**Industrial monitoring**

**Machine health monitoring**

Wireless sensor networks have been developed for machinery condition-based maintenance (CBM) as they offer significant cost savings and enable new functionality. In wired systems, the installation of enough sensors is often limited by
the cost of wiring. Previously inaccessible locations, rotating machinery, hazardous or restricted areas, and mobile assets can now be reached with wireless sensors.

**Data logging**

Wireless sensor networks are also used for the collection of data for monitoring of environmental information, this can be as simple as the monitoring of the temperature in a fridge to the level of water in overflow tanks in nuclear power plants. The statistical information can then be used to show how systems have been working. The advantage of WSNs over conventional loggers is the "live" data feed that is possible.

**Industrial sense and control applications**

In recent research a vast number of wireless sensor network communication protocols have been developed. While previous research was primarily focused on power awareness, more recent research have begun to consider a wider range of aspects, such as wireless link reliability, real-time capabilities, or quality-of-service. These new aspects are considered as an enabler for future applications in industrial and related wireless sense and control applications, and partially replacing or enhancing conventional wire-based networks by WSN techniques.

**Passive localization and tracking**

The application of WSN to the passive localization and tracking of non-cooperative targets (i.e., people not wearing any tag) has been proposed by exploiting the pervasive and low-cost nature of such technology and the properties of the wireless links which are established in a meshed WSN infrastructure.

**Smart home monitoring**

Monitoring the activities performed in a smart home is achieved using wireless sensors embedded within everyday objects forming a WSN. State changes to objects based on human manipulation is captured by the wireless sensors network enabling activity-support services.
3 DCD Algorithm

procedure DCD(C)onsider S=Source node; Neighbors of node S are A,B.
ack=active;dack=inactive

if the node A is active i.e. ack state then
    Wait for 500ms.
    Send file to node A.
else if the node A is deactive nodefailed i.e. dack state then
    file sending to A failed.
if the node B is active i.e ack state then
    Wait for 500ms.
    Send file to node B.
else if the node B is deactive nodefailed i.e dack state then
    file sending to B failed.

4 Algorithm Description

Here we briefly describe the proposed DCD algorithm. One of the nodes of the network is a specially designed node which is always active called as “source node”. Let $G = (V,E)$ denote the undirected sensor network that consists of all the nodes and edges of $G$ that are active at time $k$, where $k = 0, 1, 2 \dots$ is an iteration (repetitive) counter. Every node $p$ of node set $V$ maintains a scalar state $(x_p)(k)$ that is iteratively updated. Let the nodes of the graph $G$ execute the DCD algorithm with initial condition as $(x_0)(0) = 0 \forall p \in V$.

1. If no cut occurs or else no node fails then state of every node converges to a positive number.

2. If a cut occurs at a time $T \geq 0$ which separates the graph $G$ into $N$ connected components $(G_s),.. . , GN$, where the component $(G_s)$ ($(V_s), (E_s)$) contains the source node, then

   (a) the state of every node disconnected from the source node converges to 0 (deactive) and

   (b) the state of every node in $(V_s)$ converges to a positive number.

Hence by monitoring the states of the nodes one can know about the status
of the network connection. For effectiveness we proposed a prototype model by taking small number of nodes and their corresponding edges in the graph G. Hence the nodes can effectively detect first if there is any cut occurred and second they are still connected to source. We modified this algorithm by adding additional parameters to reduce redundant information at destination. We designed it in such a way that once the file is sent from a node, it is sent to its respective neighbors so that each and every node has the information. If there is any node failure from where information cannot be forwarded and a cut is detected, the information at the nodes is combined and then sent to the destination without the occurrence of redundancy. This approach is simulated successfully in Java environment and the expected results have found.
5 Implementation

Figure 1: The above sequence diagram depicts the transmission of data among the nodes with respect to time. Messages are denoted as labeled horizontal arrows between the life-lines (Lines which denote the scope of objects (like source node)).
Figure 2: The above class diagram shows the existence of classes (like source node, node A, etc.) and their relationship in a logical view. Each class consists of certain variables and methods declared.

6 History

The Node failure is expected to be quite common in WSN, due to their extremely limited energy budget and environmental degradation. This scenario is mostly true for the sensor networks that are deployed in harsh and dangerous environments such as forest fire monitoring. When a number of sensors fail for whatever may be the reason the resulting network topology may be disconnected which in result is considered as a failure of set of nodes. These are unsuitable for dynamic network reconfiguration and use only the single path routing approach. The network topology changes resulted by the node mobility and node state transitions due to the use of power management or energy
efficient schemes may be detected as node failures. Unexpected node failure is handled through redundancy in the network and backup pointers to reestablish damaged links. When a node failure occurs the subset of nodes get disconnected from the network which results in a "cut". The cut occurred prevents the data from reaching the destination, the subset of nodes that gets disconnected from the source form a cut area which is known as a "hole".

It is described that a wireless sensor network (WSN) typically consists of a large number of small, low-cost sensor nodes distributed over large area with one or possibly more powerful sink nodes gathering readings of sensor nodes. The sensor nodes are integrated with sensing, processing and wireless communication capabilities. The challenges due to partitioning the networks have come forward in various papers.

A paper by kleinberg et al considers the cut detection problem in wired network.

In one of the papers by G. Dini et al it proposes a method of repairing the disconnected network by using mobile nodes.

In another paper Shrivastava et al proposed a randomized and deterministic algorithm to detect network separation using a set of sentinel nodes to monitor linear cuts in a network.

In a few other papers the authors select a source node and make it broadcast a message throughout the network. Boundary nodes detect a cut if they miss that message more than a specified number of times.

Using the concept we have proposed an algorithm that not only detect an arbitrarily shaped cut but also enables every node in the network to detect a cut in distributed manner. During the transmission of data from source to destination the copy of data is sent to each and every node which may cause the problem of redundancy and memory wastage.

References


