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A Distributed Fault-Tolerant Topology

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Abstract— **This paper introduces a distributed fault-tolerant topology control algorithm, called the Disjoint Path Vector (DPV), for heterogeneous wireless sensor networks composed of a large number of sensor nodes with limited energy and computing capability and several supernodes with unlimited energy resources. The DPV algorithm addresses the k -degree Anycast Topology Control problem where the main objective is to assign each sensor's transmission range such that each has at least k -vertex-disjoint paths to supernodes and the total power consumption is minimum. There are many reactive and proactive topology control techniques for tolerating node failures in WSNs. In this paper, we focus on a proactive fault tolerant topology control algorithm in heterogeneous WSNs with a two layered architecture where the lower layer consists of low cost ordinary sensor nodes, with limited battery power and short transmission range.**

I INTRODUCTION

Wireless sensor networks (WSNs) have been studied extensively for their broad range of potential monitoring and tracking applications, including environmental monitoring, battlefield surveillance, health care solutions, traffic tracking, smart home systems and many others.

Topology control is one of the most important techniques used for reducing energy consumption and maintaining network connectivity. The upper layer consists of supernodes, which have more power reserves and better processing and storage capabilities. Links between supernodes have longer ranges and higher data rates; however, supernodes are fewer in number due to their higher cost. Supernodes can also have some special abilities like acting against an event or a certain condition. This type of supernodes are called actors (or actuators), and sensor networks that contain actors are called wireless sensor and actor networks (WSAN). In WSANs, data gathered by sensors is forwarded to actors for performing the required actions. A heterogeneous WSN with supernodes are known to be more reliable and have longer network lifetime than the homogeneous counterparts without supernodes. Heterogeneity can triple the average delivery rate and provide a fivefold increase in the network lifetime if supernodes are deployed carefully.

There are many topology control methods proposed in literature and they can be classified according to the techniques they use. Many topology control methods are built on the transmit power adjustment technique which depends on the ability of sensors to control their transmit power. Some algorithms use sleep scheduling which aims to decrease energy consumption while nodes are in idle state. Others use geometrical structures, location and direction information and also combinations of these techniques. IN Existing System They propose a greedy centralized algorithm called global anycast topology control (GATC), and also a distributed algorithm called distributed anycast topology control (DATC), which provides k-vertex supernode connectivity by incrementally adjusting the transmission range of the sensor nodes. GATC is mostly of theoretical importance since it is not practical to apply it for large scale WSNs due to the requirement of global topology knowledge. In DATC, each node starts with a minimal set of neighbours and minimal power level. The power level is increased incrementally and only the paths from the neighbourhood that is reachable with that power level can be discovered. The nodes outside of the reachable neighbourhood are totally unknown to the node performing discovery and thus they are out of the search scope for discovering paths.

Disadvantages: In Existing works, each node starts with a minimal set of neighbours and minimal power level. The power level is increased incrementally and only the paths from the neighbourhood that is reachable with that power level can be discovered. The nodes outside of the reachable neighbourhood are totally unknown to the node performing discovery and thus they are out of the search scope for discovering paths.

Sensor nodes collaborate in a distributed and autonomous manner to accomplish a certain task, usually in an environment with no infrastructure. Power efficiency and fault tolerance are essential properties to have for WSNs in order to keep the network functioning properly in case of energy depletion, hardware failures, communication link errors, or adverse environmental conditions, events that are likely to occur quite frequently in WSNs

II LITERATURE REVIEW

Topology control algorithms for wireless sensor networks: A critical survey

In a densely deployed wireless sensor network, a single node has many neighbouring nodes with which direct communication would be possible when using sufficiently large transmission power. This is, however, not beneficial; high transmission power requires lots of energy, many neighbours are a burden for a MAC protocol, and routing protocols suffer from volatility in the network when nodes move around. To overcome these problem topology control can be applied. The idea is to deliberately restrict the set of nodes that are considered neighbours of a given node.

FLSS: A Fault-Tolerant Topology Control Algorithm for Wireless Networks

The development of wireless communication in recent years has posed new challenges in system design and analysis of wireless networks, among which energy efficiency and network capacity are perhaps the most important issues. As such, topology controls algorithms have been proposed to maintain network connectivity while reducing energy consumption and improving network. However, by reducing the number of links in the network, topology control algorithms actually decrease the degree of routing redundancy, and hence the topology thus derived is more susceptible to node failures/departures. In this paper, we consider k -vertex connectivity of a wireless network. We first present a centralized greedy algorithm, called Fault-tolerant Global Spanning Subgraph (FGSS k), which preserves k -vertex connectivity. FGSS k is min-max optimal, i.e., FGSS k minimizes the maximum transmission power used in the network, among all algorithms that preserve the k -vertex connectivity.

Based on FGSS k, we then propose a localized algorithm, called Fault-tolerant Local Spanning Subgraph (FLSS k). We formally prove that FLSS k preserves k -vertex connectivity while maintaining bi-directionality of the network. We also prove FLSS k is min-max optimal among all strictly localized algorithms. Finally, we relax several widely used assumptions for topology control, in FGSS k and FLSS k so as to enhance their practicality.

The K-Neigh Protocol for Symmetric Topology Control in Ad Hoc Networks

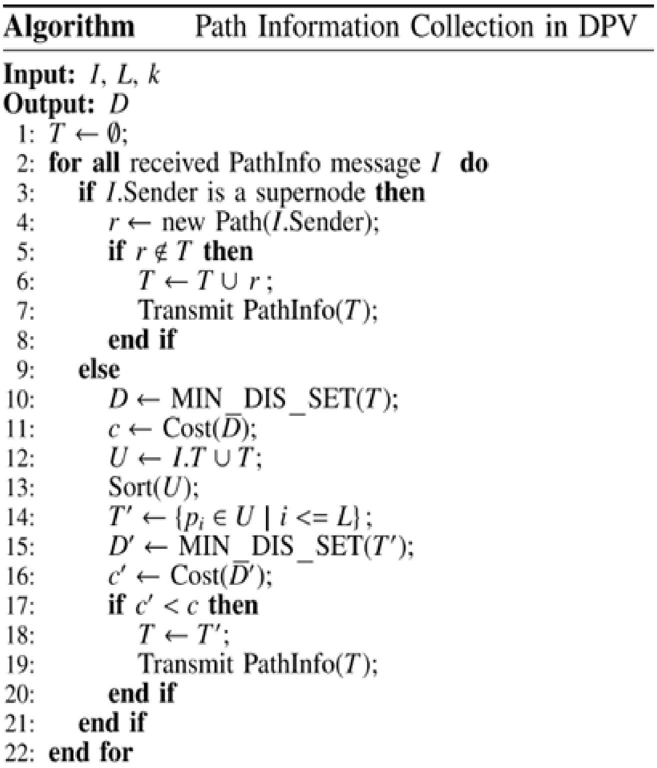
We propose an approach to topology control based on the principle of maintaining the number of neighbours of every node equal to or slightly below a specific value k. The approach enforces symmetry on the resulting communication graph, thereby easing the operation of higher layer protocols. To evaluate the performance of our approach, we estimate the value of k that guarantees connectivity of the communication graph with high probability. We then define k -Neigh, a fully distributed, asynchronous, and localized protocol that follows the above approach and uses distance estimation. We prove that k -Neigh terminates at every node after a total of 2 n messages have been exchanged (with n nodes in the network) and within strictly bounded time.

Span: An Energy-Efficient Coordination Algorithm for Topology Maintenance in Ad Hoc Wireless Networks

This paper presents Span, a power saving technique for multi-hop ad hoc wireless networks that reduces energy consumption without significantly diminishing the capacity or connectivity of the network. Span builds on the observation that when a region of a shared-channel wireless network has a sufficient density of nodes, only a small number of them need be on at any time to forward traffic for active connections. Span is a distributed, randomized algorithm where nodes make local decisions on whether to sleep, or to join a forwarding backbone as a coordinator. Each node bases its decision on an estimate of how many of its neighbours will benefit from it being awake, and the amount of energy available to it. We give a randomized algorithm where coordinators rotate with time, demonstrating how localized node decisions lead to a connected, capacity-preserving global topology. Improvement in system lifetime due to Span increases as the ratio of idle-to-sleep energy consumption increases.

III PATH INFORMATION COLLECTION:

- In this module, initiated by the supernodes through Init messages. An Init message contains the ID of the supernode that created the message and can only be transmitted by a supernode.



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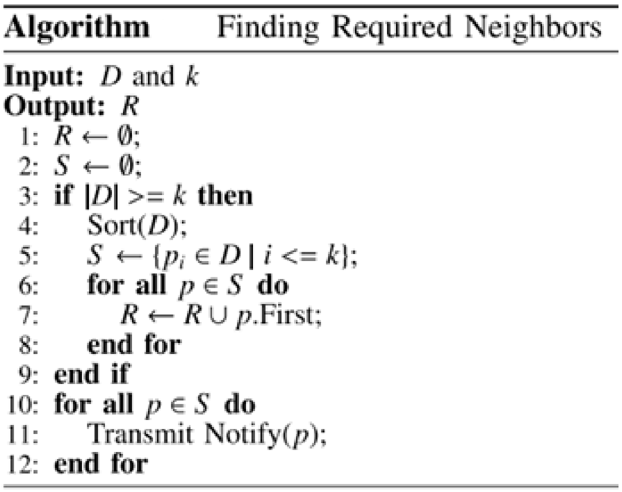
Algorithm    Path Information Collection in DPV
Input: $I, L, k$
Output: $D$
$T \leftarrow \emptyset$;
for all received PathInfo message $I$ do
    if $I$.Sender is a supernode then
        $r \leftarrow$ new Path($I$.Sender);
        if $r \notin T$ then
            $T \leftarrow T \cup r$;
            Transmit PathInfo($T$);
        end if
    else
        $D \leftarrow$ MIN_DIS_SET($T$);
        $c \leftarrow$ Cost($\bar{D}$);
        $U \leftarrow I.T \cup T$;
        Sort($U$);
        $T' \leftarrow \{p_i \in U \mid i <= L\}$;
        $D' \leftarrow$ MIN_DIS_SET($T'$);
        $c' \leftarrow$ Cost($\bar{D}'$);
        if $c' < c$ then
            $T \leftarrow T'$;
            Transmit PathInfo($T$);
        end if
    end if
end for
```

- These messages are received by the sensor nodes in the network and each receiver node updates its local path information according to that data.
- Sensor nodes transmit PathInfo messages when an update occurs in their local disjoint path lists. Upon receiving a PathInfo message, each sensor node computes the disjoint paths to the supernodes by using its local data and the path information received from the PathInfo message.
- If the incoming PathInfo message decreases the cost of the disjoint paths, the message is forwarded by adding the

updated path information. The cost of a set of disjoint paths is defined as the maximum of the costs of the paths in the set.



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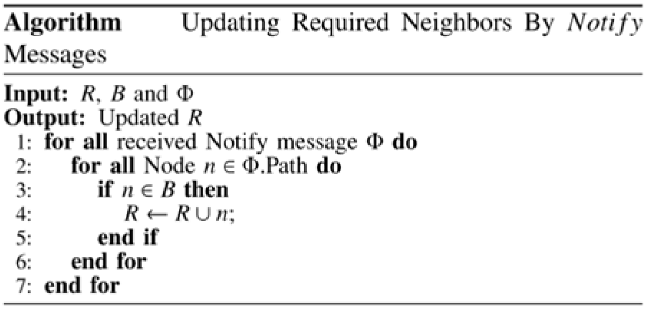
Algorithm    Finding Required Neighbors
Input: $D$ and $k$
Output: $R$
$R \leftarrow \emptyset$;
$S \leftarrow \emptyset$;
if $|D| >= k$ then
    Sort($D$);
    $S \leftarrow \{p_i \in D \mid i <= k\}$;
    for all $p \in S$ do
        $R \leftarrow R \cup p$.First;
    end for
end if
for all $p \in S$ do
    Transmit Notify($p$);
end for
```

FINDING EACH SENSOR NODES REQUIRED NEIGHBORS:

- When further decrement is not possible, the first stage of the algorithm ends and the second stage starts in which each node calculates its required neighbors using the locally found set of disjoint paths as the input.

UPDATING REQUIRED NEIGHBORS BY NOTIFICATION MESSAGES:

- To guarantee that all nodes in a selected disjoint path are labeled as required neighbors, we need to notify all the nodes on that path.
- To achieve this, each node sends a Notify message for each of its selected disjoint paths. A Notify message is forwarded along the disjoint path for which it was created. Each neighboring node in the disjoint path marks each other as required neighbors.
- This stage ensures that any node on a selected disjoint path will be marked as a required neighbor of its neighbors that are also on the same disjoint path.
- If any two neighbor nodes do not mark each other as required neighbors, it means that the link between these two nodes is not necessary and can be removed.



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Algorithm    Updating Required Neighbors By Notify Messages
Input: $R$, $B$ and $\Phi$
Output: Updated $R$
for all received Notify message $\Phi$ do
    for all Node $n \in \Phi$.Path do
        if $n \in B$ then
            $R \leftarrow R \cup n$;
        end if
    end for
end for
```

PACKET TRANSMISSION:

- In this module sensor node sends a sensed value to based station through minimum shortest path.
- This path contains required sensor nodes with some super node. Finally this sensed values are transformed to base station.
- Now base station stored this sensed values to its own storage.

PROCESS DIAGRAM

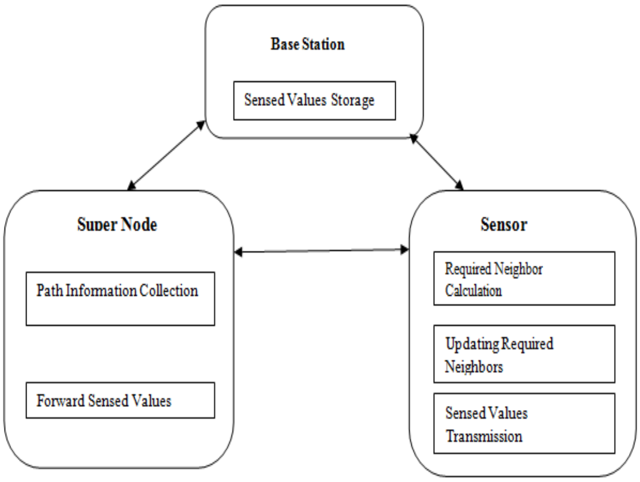

Figure 1: Process Diagram

IV EXISTING SYSTEM

- Many topology control methods are built on the transmit power adjustment technique which depends on the ability of sensors to control their transmit power.
- Some algorithms use sleep scheduling which aims to decrease energy consumption while nodes are in idle state.
- Others use geometrical structures, location and direction information and also combinations of these techniques.
- The difference between these studies and our work is that we try to minimize nodes' total transmission power in two-tiered heterogeneous topologies whereas other works focus on flat homogeneous topologies. In addition we focus on connectivity between a sensor node and supernodes whereas they focus on connectivity between any two nodes.
- Clustering can also be considered as another way of topology control, where the aim is to organize the network into a connected hierarchy for the purpose of balancing load among the nodes and prolonging the network lifetime.
- Hierarchical clustering techniques select cluster heads depending on various criteria and create a layered architecture. However, these techniques start with a flat topology and end up with a layered one.
- On the other hand, west art with a layered architecture from the beginning, where the supernodes are already given. Instead of building clusters, we focus on maintaining fault-tolerant connectivity between sensor nodes and supernodes.
- The links between sensors and actors are assumed to be less reliable, hence there are several methods proposed for

maintaining reliable sensor-actor connectivity. The methods, however, do not employ k-connectivity between sensors and actors and thus they do not guarantee fault-tolerance in case of k - 1 node failures.

- Although addresses the k-actor connectivity problem, it does not consider the energy efficiency of the resulting topologies.
- **Disadvantages**: In Existing works, each node starts with a minimal set of neighbors and minimal power level. The power level is increased incrementally and only the paths from the neighborhood that is reachable with that power level can be discovered. The nodes outside of the reachable neighborhood are totally unknown to the node performing discovery and thus they are out of the search scope for discovering paths.

V CONCLUSION

In this paper we introduce a new distributed and fault-tolerant algorithm, called Disjoint Path Vector Algorithm (DPV), for constructing fault-tolerant topologies for heterogeneous wireless sensor networks consisting of supernodes and ordinary sensor nodes. Our algorithm results in topologies where each sensor node in the network has at least k-vertex disjoint paths to the supernodes. The objective of the algorithm is to minimize the total transmission power of the nodes in the network. Through extensive simulations, we show that our approach outperforms the existing algorithms in terms of energy efficiency.

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