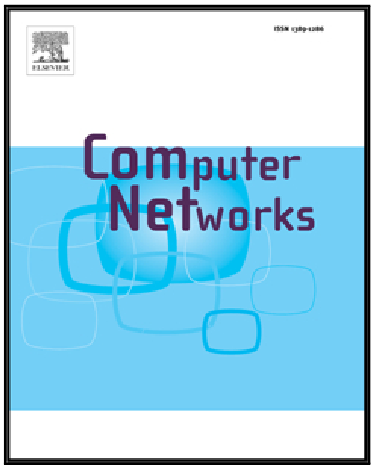
Accepted Manuscript



Optimized Repair of a Partitioned Network Topology

Wassila Lalouani , Mohamed Younis , Nadjib Badache

PII: S1389-1286(17)30041-5
DOI: 10.1016/j.comnet.2017.02.003
Reference: COMPNW 6102

To appear in: *Computer Networks*

Received date: 26 July 2016
Revised date: 18 January 2017
Accepted date: 6 February 2017

Please cite this article as: Wassila Lalouani , Mohamed Younis , Nadjib Badache , Optimized Repair of a Partitioned Network Topology, *Computer Networks* (2017), doi: 10.1016/j.comnet.2017.02.003

Optimized Repair of a Partitioned Network Topology

Wassila Lalouani[*], Mohamed Younis[**], and Nadjib Badache[***]

[*]High National School of Computing Science, Algiers, Algeria. Email: w_lalouani@esi.dz
[**]Dep.t of Computer Science and Elect. Eng., University of Maryland Baltimore County. Email:younis@cs.umbc.edu
[***]Department of Theories and Computer Engineering, CERIST, Algiers, Algeria. Email: badache@mail.cerist.dz

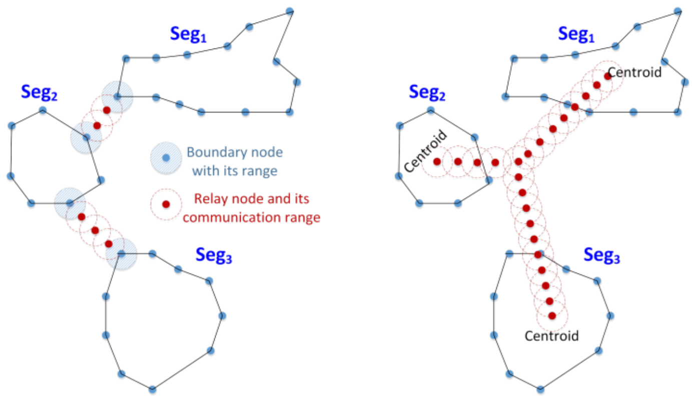
***Abstract*—We consider the problem of deploying the least count of relay nodes to restore connectivity in a network that got partitioned into multiple disjoint segments. Such a problem has been generally formalized as a Steiner Minimum Tree (SMT) by assuming that each segment is a terminal, e.g., by picking a single node in a segment to serve as an interface point. We argue that such formulation is ineffective since the size and the shape of the segment are not factored in. To overcome this drawback, we propose a novel approach for Boundary-aware optimized Interconnection of Disjoint segments (BIND). BIND opts to restore network connectivity by forming the shortest length topology in the Euclidean plane that interconnects a subset of nodes on the segment boundaries through extra Steiner points so that there is a path between every pair of segments. Since constructing the SMT connecting boundary nodes (terminals) subject to obstacle avoidance is NP-hard, BIND pursues a heuristic based on the generation and concatenation of full Steiner trees (FSTs). As the number of distinct FSTs grows exponentially with the number of terminals, BIND further promotes a new geosteiner technique based on the straight skeleton of the segment boundaries within the deployment area in order to reduce the complexity. The simulation results confirm the effectiveness of BIND and its advantage compared to competing schemes.**

***Keywords:* Topology repair; Fault tolerance; relay node placement; connectivity restoration, ESTPO.**

I. Introduction

In wireless networks that operate in harsh environments nodes may be susceptible to electronic breakdown and even damage. In these cases, the failure of nodes not only could determent the coverage quality of the monitored area, but also break some communication paths among nodes. Example application scenarios include the deployment of a network to serve security surveillance of a vast border, search-and rescue in disaster area, reconnaissance of a combat field, etc. In addition, the node failure may be due to depleted energy supply or the small form-factor of the node design, e.g., the case of wireless sensor network (WSNs). When only a single node is lost, the effect on the network connectivity is minimal unless the failed node serves as a cut-vertex, i.e., gateway, in the topology causing the network to be split to disjoint segments. A single node failure often can be detected by neighboring nodes through the exchange of periodic heartbeat messages and failure tolerance can be autonomously achieved by the coordinated relocation of these neighboring nodes to restore the connectivity. However, such a recovery process is ineffective in case the scope of failure involves multiple collocated nodes. This failure scenario may be experienced in applications such as battlefield surveillance, forest fire detection, volcano monitoring, etc. where parts of the area get affected by an explosion, fire, lava, etc. Basically, the scope of the damage in this case is too broad to be determined by the healthy nodes in the vicinity and thus coordinated repositioning of some nodes will not be feasible as a recovery strategy due to the loss of many communication links [1].

Published schemes for overcoming the simultaneous failure of multiple collocated nodes mostly pursue centralized recovery strategies [2]-[18]. Basically, additional mobile nodes are deployed to serves as relay nodes among the isolated segments. The



(a) (b)

Figure 1: Illustrating the dramatic effect of segment size and shape on the relay count required for establishing connectivity. A circles denotes the relay communication range; (a) the links between segments reflect the solution while factoring in the boundary nodes, where a total of 5 relays will be needed. Note that Seg_2 has two interface points. Seg_1 and Seg_3 are connected through a path that uses all new relay nodes and leverage the inter-segment links of Seg_2 (recall that segments are strongly connected; (b) an inter-segment topology linking the centroids of segments, i.e., SMT for the centroids, employs 23 relays to federate the network in this case. Obviously using a single interface point in this case is a costly solution.