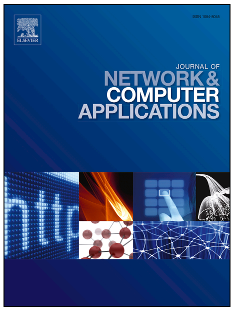
Accepted Manuscript



Interconnecting isolated network segments through intermittent links

Wassila Lalouani, Mohamed Younis, Nadjib Badache

PII: S1084-8045(18)30055-9

DOI: 10.1016/j.jnca.2018.02.010

Reference: YJNCA 2069

To appear in: *Journal of Network and Computer Applications*

Received Date: 21 September 2017

Revised Date: 21 December 2017

Accepted Date: 17 February 2018

Please cite this article as: Lalouani, W., Younis, M., Badache, N., Interconnecting isolated network segments through intermittent links, *Journal of Network and Computer Applications* (2018), doi: 10.1016/j.jnca.2018.02.010.

Interconnecting Isolated Network Segments through Intermittent Links

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* - Wireless Sensor Network (WSN) deployed within hostile environments may suffer from large scale damage where many sensors fail simultaneously and cause the WSN to split into disconnected segments. Restoring inter-segment connectivity is primordial to the effectiveness of the WSN. When it is not feasible to replace the lost nodes, a set of mobile relays is often employed in order to establish intermittent connectivity between segments. Basically these relays serve as mobile data carriers (MDCs) that tour segments to transport the data. A key objective is to minimize the tour length in order to limit the travel overhead and data latency. Existing solutions have simplified the optimization problem by representing each segment by just one terminal and ignoring the shape and the size of the individual segments. In this paper, we consider the recovery optimization under realistic segment topology and constrained number of MDCs, which make the problem very challenging. We present a two-step heuristic for Connecting Isolated Segments through Intermittent Links (CISIL). CISIL first uses a high order Delaunay triangulation to efficiently determine all efficient tours among segments, and then selects the optimal subset of these tours that matches the MDC count and yields a strongly connected network. The selection optimization is mapped to a *k*-edge minimum spanning tree problem within a hypergraph. The performance of CISIL is validated through simulation and compared to a prominent competing scheme.**

***Keywords* - Sensor networks, connectivity restoration, failure recovery, mobile data carriers, federating network segments.**

I. INTRODUCTION

Wireless sensor network (WSNs) can be beneficial in many applications like forest monitoring, target tracking, and battlefield surveillance. In many applications, the sensor nodes are deployed within hostile environments which make them highly susceptible to failure. For example a WSN serving in a battlefield could be impacted by explosive; similarly nodes could fail due to any disastrous event like forest fires. The severity of the events in these scenarios may be so significant that the scope of the damage includes many collocated sensors and causes the network to be fragmented into isolated segments [1]. Restoring connectivity after these events and with limited resources is critical for the continuation of the WSN services. Contemporary solutions either deploy additional nodes or identify some of the survived nodes in the network to be reassigned a different role without negatively affecting the application. For example, nodes may be relocated [2], or additional relays are deployed [3]-[7] to restore connectivity by forming stable inter-segment links.

However, when the number of available nodes, within the network or externally supplied, is insufficient for forming a connected inter-segment topology, existing solutions [8]-[22] tend to establish intermittent links by employing multiple mobile data carriers (MDCs). Basically, these MDCs tour the individual segments to transport data from one segment to another. Every MDC has to tour part of the area such that some of the network segments along the MDC's travel path are visited regularly to collect and transport data from and towards its designed segments. The tours are to be formed such that each segment could be reachable to every other segment in the WSN. In essence the segments are federated rather than tightly-coupled in this case. The number of tours should be determined based on the number of available MDCs, *k*. As the movement of the MDCs incurs significant energy overhead that diminishes their lifespan, which has a direct impact on the quality of the federation service for the application, the main objective of the interconnection solution is to find the shortest *k*-tours.

Published heuristics that form *k*-tours to restore connectivity generally formulate the problem by representing each segment by one terminal. Basically, the network is modeled as a general graph of terminals and then clustering techniques are exploited to deal with the MDC count constraint. However, the topological properties of the damaged area as well as the size and shape of segments are not factored in when forming the tours. Such a limitation significantly detriments the quality of existing solutions since in practice a segment could be accessible to multiple MDCs using distinct boundary nodes and could exploit intra-segment links to disseminate the data within the segment. As illustrated in Figure 1, the consideration of boundary nodes significantly reduces the length of the tours and the energy required for MDCs displacement. The figure illustrates clearly the advantage of exploiting the exact segment topology in order to federate the network. To overcome the aforementioned shortcoming of the existing solutions, this paper proposes a novel approach for boundary-aware tour formation. Specifically, we focus on the interconnection problem using *k* MDCs necessary for forming inter-segment topology while considering multiple interfaces for each segment. To do so, we represent each segment by a simple polygon delimited by its boundary nodes. To the best of our knowledge such a federation problem has not been investigated before in the literature.