Int. J. Electron. Commun. (AEÜ) 68 (2014) 489–495

Contents lists available at ScienceDirect

International Journal of Electronics and Communications (AEÜ)

journal homepage: www.elsevier.com/locate/aeue

Heuristic approach for broadcast scheduling, problem in wireless mesh networks

D. Arivudainambi [a,*], D. Rekha [b]

[a] Anna University, Chennai, India
[b] VIT University, Chennai, India

ARTICLE INFO

Article history:
Received 25 July 2012
Accepted 12 December 2013

Keywords:
Broadcast scheduling problem
Memetic algorithm
Spatial reuse
Wireless mesh network

ABSTRACT

Disasters can be natural and human-initiated events that interrupt the usual functioning of people on a large scale. Region where disasters have occurred causes hazards to the public of that area and to the rescue teams. Disaster causes the damage to the communication network infrastructure also. Once the communication infrastructure is damaged, it is very difficult to the rescue teams to actively involve in relief operation. To handle these hazards, different wireless technologies can be initiated in the area of disaster. This paper discusses the innovative wireless technology for disaster management. Specifically, issues related to the broadcast scheduling problem in wireless mesh network is deployed efficiently during disaster relief are discussed. A domain specific memetic algorithm is proposed for solving the optimum time division multiple access broadcast scheduling problem in wireless mesh networks. The aim is to increase the total number of transmissions in optimized time slot with high channel utilization in a less computation time. Simulation results showed that our memetic algorithm approach to this problem achieves 100% convergence to solutions within reduced computation time while compared to recent efficient algorithms. The results were compared with several heuristic and non-heuristic algorithms for broadcast scheduling problem.

1. Introduction

Over the past decade, the world has perceived sequence of natural and man-made disasters such as terrorist attacks on the World Trade Center in New York (2001), Indian Ocean Earthquake/Tsunami in Asia (2004), Hurricane Katrina (2005), Haiti earthquake (2010), Japan Earthquake, Tsunami and Nuclear Crisis (2011). The number of people affected and the material damage caused due to this have been growing substantially. An essential part of handling disaster is the ability to communicate the information over long distances in a short time. Disaster response and recovery requires appropriate communication and coordination in that area. A traditional solution to handle disasters was the wired communication network deployed over long distances. Though wired communication works well during normal operations and easy to use, still, sometimes they fail to satisfy the extreme conditions. Wired communication is susceptible to failure during disasters as cable breakage interrupts the communication.

Wireless communication networks are measured as the most reliable and flexible communication for disaster relief [9,18]. Public safety organizations are mostly depending on wireless communication to provide helpful control and communication during disaster reaction process. Wireless technology plays a major role in information sharing during the disasters. Wireless communication technology offers several benefits over the other land based or cellular technologies. In this paper, we have proposed how efficiently broadcasting can be done in wireless mesh network, which will be useful during a disaster relief.

A wireless mesh network (WMN) is dynamically self-organized and self-configured, with the nodes in the network automatically establishing and maintaining mesh connectivity among themselves. Self-organized wireless nodes that use wireless relaying for data transfer construct WMNs. The self-healing capability enables a fault tolerant network to operate when one node fails down. Because of this, the network is quite reliable since there is more than one path between a source and a target in the network. This feature makes advantages to WMNs such as easy network maintenance, robustness, reliable service coverage and used for disaster management.

In WMNs nodes are comprised of mesh routers and mesh clients, each node operates not only as a host but also as a router. Every node forward packets on behalf of other nodes that may not be within direct wireless transmission range of their destinations. The main characteristic of WMNs is Multi-hop wireless network. The purpose to develop WMNs is to extend the coverage range of

* Corresponding author. Tel.: +91 044 22358520.
E-mail addresses: arivu@annauniv.edu (D. Arivudainambi), rekhadurai@gmail.com, rekha.d@vit.ac.in (D. Rekha).

1434-8411/$ – see front matter
http://dx.doi.org/10.1016/j.aeue.2013.12.009

current wireless networks without giving up the channel capacity. Another objective is to provide non-line-of-sight (NLOS) connectivity among the users without direct line-of-sight (LOS) links. To meet these requirements, the mesh-style multi-hopping is indispensable, which attain higher throughput without sacrificing effective radio range via shorter link distances, less interference between the nodes, and more efficient frequency re-use [10].

WMNs are best suited for Emergency/Disaster Communications. For instance, wireless networks for a disaster response team do not have in advance knowledge of where the network should be deployed. Simply placing wireless mesh routers in the desired region, a WMN can be quickly established. Using this group of people having devices with wireless networking capability the communication is initiated anytime anywhere for information sharing in the disaster area. WMNs are a superset of ad hoc networks and can achieve all functions provided by ad hoc networking.

In wireless mesh networks adopts a time division multiple access (TDMA) MAC protocol. TDMA is divided into frames where each frame is further divided into time slots. Each time slot can be assigned to different nodes and in a single frame all nodes must be allowed to transmit packets at least once. Spatial reuse is used to increase TDMA transmission by allowing several nodes to use the same time slot if they are far enough in space and without making interference. Spatial reuse TDMA (STDMA) is an access method for multihop radio networks. STDMA scheduling algorithms are categorized into link scheduling and broadcast/node scheduling algorithms. In a wireless mesh network, a link is represented as (t, r), where t is a transmitter and r is a receiver. In link scheduling, the transmission in every slot is assigned to certain links, where as in broadcast scheduling the transmission in every slot is assigned to certain nodes and every neighbor can receive the packet transmitted by a node.

In this paper, we consider WMNs with TDMA and we represented its topology as graph. As wireless mesh networks operate in a time slotted mode, it is also necessary to allocate time slots without collision over the network to achieve assigned bandwidth for each connection. The broadcast scheduling problem is modeled using memetic algorithm by taking into account the interference constraints. The aim of the algorithm is to activate all the nodes at least once, with minimum number of time slots and to improve the utilization factor of the network channels, i.e., to increase the number of transmissions.

Several algorithms are proposed for broadcast scheduling problem in various networks. Few approaches are finite state machine synthesis approach for ad hoc TDMA networks [1], genetic algorithm for packet radio networks [8], hysteretic noisy chaotic neural network for packet radio networks [12], genetic-fix algorithm for packet radio networks [14], tabu-greedy algorithm for packet radio networks [15], algorithm with Hopfield neural network for the constraints satisfaction and genetic algorithm for achieving maximal throughput in packet radio network [16], linear integer programming formulation for broadcast scheduling problem in packet radio networks [17], mean field annealing approach for packet radio networks [19] competent permutation genetic algorithm for mobile ad hoc networks[20], gradual noisy chaotic neural network for packet radio networks [11], memetic algorithm approach for multi hop and ad hoc networks [2–4], combinatorial algorithm in [5] and variations of a Greedy Randomized Adaptive Search Procedure in [6,7].

A finite state machine synthesis approach for the broadcast scheduling problem is proposed in [1], which determines the minimum frame length with the maximum slot utilization. A maximal compatible set of nodes is produced and these are chosen such that the nodes in that set do not have conflicts with one another. A tight lower bound derived from set of maximal incompatibles forms the basis for deriving minimum frame length. The algorithm applies set of rules on the maximal compatibles in order to maximize utilization of slots.

A novel hysteretic noisy chaotic neural network (HNCNN) by controlling noises of the equivalent model for broadcast scheduling problem in packet radio networks is given in [12]. They combine the HNCNN with the gradual expansion scheme to find the minimal frame length in the first phase, and to maximize the conflict-free transmission in the second phase.

A mixed tabu-greedy algorithm has been implemented to solve the broadcast scheduling problem in packet radio networks is given in [15]. Improvements are achieved in terms of both channel utilization and packet delay by using a two-step algorithm. A linear integer programming formulation for the composite problem of maximizing channel utilization while minimizing the length of the frame is given in [17] that performs in reduced computation time but maximum number of stations taken in their approach is 50 stations.

Three step broadcast scheduling algorithm based on mean field annealing (MFA) neural networks is proposed in [19]. The first step reduces solution space by presetting some neurons according to the topology of scheduling network. Second step executes MFA procedure to maximize channel utilization. A heuristic approach is the final step to arrange transmissions of unassigned stations.

Genetic algorithm (GA) is population-based stochastic optimization method with an iterative process of generation-and-test. It has been recognized that GA is promising approach for NP-hard or NP-complete problems. GA solves many search and optimization problems effectively. A standard genetic algorithm approach is given by Chakraborty in 1998 for scheduling problem in packet radio networks, though the algorithm able to solve small problems but performs poorly for large networks. This is because classical crossover and mutation operations create invalid population that goes through several generations and delay the progress of search for valid solutions. Special crossover and mutation operations for elite population method are defined by Chakraborty in [8], such that members of the population always remain valid solutions for the problem. Even though it reduces invalid solutions and number of generations to produce optimal solution, computation time is not reduced.

An approach based on a modified GA called genetic-fix is given in [14]. They formulate the problem based on a within-two-hop connectivity matrix and propose a centralized scheduling algorithm using a modified genetic-fix algorithm. Traditional GA generates subsets of all possible sizes whereas genetic-fix algorithm generates fixed-size subsets i.e., in binary representation number of one's is fixed.

A procedure that combines Hopfield neural network for the constraints satisfaction and genetic algorithm for achieving maximal throughput are proposed in [16]. Their approach to solve broadcast scheduling problem is by dividing problem in two sub problems. The first is to find minimum frame length without interference using discrete Hopfield neural network. The second increases the throughput for given frame length is done by combining Hopfield neural network with genetic algorithm.

A competent permutation encoded genetic algorithm is executed to solve optimum time division multiple access broadcast scheduling problem for mobile ad hoc networks in [20]. The problem search space is reduced mostly and genetic algorithm becomes more capable in searching the optimum solutions.

In genetic algorithm, the mutation creates new genes for the population and crossover operator orients seeking the best solution from genes in the population. However, they may drop into local optimal solutions or they may find optimal solution by low convergence speed and GA blindly wanders over search space. In GA, a normal mutation operator takes chance to change a best solution obtained from previous operation.