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Ad Hoc Wireless Networks QOS Enhancement-Dynamic Simulation Approach

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Abstract: ***in this work, a new approach is introduced for energy saving control problem in ad hoc wireless networks. This project discusses the energy saving control problem in ad hoc wireless networks. The inputs of the problem are given as a set of nodes in a plane, end-to-end traffic demands and delay bounds between node pairs, the problem is to find an optimized routing that can meet the Quality of Service requirements and the total power of nodes is minimized. We consider the case in which the traffic demands are not splittable. The problem is formulated as an Integer Linear Programming problem. An optimal algorithm has been proposed to solve the problem. A new constraint is added which distributes the power consumption. This is in turn minimize the variance of the power vector for the topology nodes. Inputs are given as a set of nodes in a plane, end-to-end traffic demands and delay bounds between node pairs, the problem is to find an optimized routing that can meet the Quality of Service requirements and the variance of the power vector for the nodes is minimized. The variance is decreased by almost 50%.***

Keywords: Topology control, energy saving control, Quality of Service requirement, routing in mobile ad hoc Network.

1. Introduction

An ad hoc wireless network is a special type of wireless networks that does not have a wired infrastructure to support communication among the wireless nodes. In multi-hop ad hoc networks, communication between two nodes that are not direct neighbors requires the relay of messages by the intermediate nodes between them. Each node acts as a router, as well as a communication end-point. An ad-hoc wireless network is a decentralized type of wireless network. The network is ad hoc because it does not rely on a preexisting infrastructure, such as routers in wired networks or access points in managed infrastructure wireless networks. Instead, each node participates in routing by forwarding data for other nodes, and so the determination of which nodes forward data is made dynamically based on the network connectivity. In addition to the classic routing, ad hoc networks can use flooding for forwarding the data. An ad hoc network typically refers to any set of networks where all devices have equal status on a network and are free to associate with any other ad hoc network devices in link range. The decentralized nature of wireless ad-hoc networks makes them suitable for a variety of applications where central nodes can't be relied on, and may improve the scalability of wireless ad-hoc networks compared to wireless managed networks, though theoretical and practical limits to the overall capacity of such networks have been identified. An ad-hoc network is made up of multiple nodes connected by links. Links are influenced by the node's resources (e.g. transmitter power, computing power and memory) and by behavioral properties (e.g. reliability), as well as by link properties (e.g. length-of-link and signal loss, interference and noise). Since links can be connected or disconnected at any time, a functioning network must be able to cope with this dynamic restructuring, preferably in a way that is timely, efficient, reliable, robust and scalable. In most wireless ad hoc networks, the nodes compete for access to shared wireless medium, often resulting in collisions interference. Using cooperative wireless communications improves immunity to interference by having the destination node combine self-interference and other-node interference to improve decoding of the desired signal. There are many modern network applications that require QoS provisions in ad hoc networks, such as transmission of multimedia data, real-time collaborative work, and interactive distributed applications. In multi-hop ad hoc networks, on-line QoS provisions, such as end-to-end bandwidth and delay, are highly dependent on the network topology. Many studies have been done on QoS provisions in ad hoc networks, such as QoS routing or admission control [3].Without a proper configuration of the topology, some nodes in the network could be easily over-loaded and it might be impossible to find a QoS route during the operation of the network. The topology of an ad hoc network can be controlled by some controllable

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parameters such as transmitting power and antenna directions. Topology control is to allow each node in the network to adjust its transmitting power (i.e., to determine its neighbors) so that a *good* network topology can be formed. An issue associated with topology control is often energy management.

In ad hoc wireless networks, each node is usually powered by a battery equipped with it. Since the capacity of battery power is very much limited, energy consumption is a major concern in topology control. To increase the longevity of such networks, an important requirement of topology control algorithms is to achieve the desired topology by using minimum energy consumption. Given a set of wireless nodes in a plane and QoS requirements between node pairs, our problem is to find a network topology that can meet the QoS requirements and the maximum transmitting power of nodes is minimized. The QoS requirements of our concern are traffic demands (bandwidth) and maximum delay bounds Z (in terms of hop counts) between end-nodes at the application level. With the network configured in such a topology, as many as possible QoS calls can be admitted at run-time and the network life time can be prolonged. For obtaining QoS, it is not sufficient to provide a basic routing functionality. Other aspects should also be taken into consideration such as *bandwidth* due generally to a shared media, and the topology may change and *power consumption* due to limited batteries. Bandwidth defines the net bit rate, channel capacity, or the maximum throughput of a logical or physical communication path in a digital communication system. For example, bandwidth tests measure the maximum throughput of a computer network. The reason for this usage is that according to Hartley's law, the maximum data rate of a physical communication link in bit/s may also refer to consumed bandwidth, corresponding to achieved throughput or good put, i.e., the average rate of successful data transfer through a communication path. This sense applies to concepts and technologies such as bandwidth shaping, bandwidth management, bandwidth throttling, bandwidth cap, bandwidth allocation (for example bandwidth allocation protocol and dynamic bandwidth allocation), etc.

A bit stream's bandwidth is proportional to the average consumed signal bandwidth in Hertz (the average spectral bandwidth of the analog signal representing the bit stream) during a studied time interval. Channel bandwidth may be confused with data throughput. A channel with *x* bps may not necessarily transmit data at *x* rate, since protocols, encryption, and other factors can add appreciable overhead. For instance, a lot of internet traffic uses the transmission control protocol (TCP) which requires a three-way handshake for each transaction, which, though in many modern implementations is efficient, does add significant overhead compared to simpler protocols. In general, for any effective digital communication, a framing protocol is needed; overhead and effective throughput depends on implementation. Actual throughput is less than or equal to the actual channel capacity.

2. Related Work

The earlier works of topology control can be found in [2, 11, 12]. An analytic model was developed to allow each node to adjust its transmitting power to reduce interference and hence achieve high throughput. In some research works, a distributed algorithm was developed for each node to adjust its transmitting power to construct a reliable high-throughput topology. Minimizing energy consumption was not a concern in both works. Recently, energy efficient topology control becomes an important topic in ad hoc wireless networks. Most of the works have been focused on the construction and maintenance of a network topology with good (or required) connectivity by using minimal power consumption. Lloyd et al. gave a good summary of the works in this type in [4]. They use a 3-tuple <M, P, O> to represent topology control problems, where “M” represents the graph model (either directed or undirected), “P” represents the desired graph property (e.g., 1-connected or 2-connected), and “O” represents the minimization objective. The NP-completeness of this kind of problems has been analyzed and several algorithms have been proposed. In [4, 6], two centralized optimal algorithms were proposed for creating connected and biconnected static networks with the objective of minimizing the total transmitting power for the nodes. Additionally, two distributed heuristics, LINT (local information no topology) and LILT (local information link-state topology), were proposed for adaptively adjusting node transmitting power to maintain a connected topology in response to topological changes. But, neither LINT nor LILT can guarantee the connectivity of the network. Li et al. proposed a minimum spanning tree based topology control algorithm that achieves network connectivity with minimal power consumption [9]. A cone-based distributed topology control method was developed in [10]. Basically, each node gradually increases its transmitting power until it finds a neighbor node in every direction (cone). As the result, the global connectivity is guaranteed with minimum power for each node. Huang et al. extended this work in [12] to the case of using directional antennas [11]. Another method to optimize the topology of Bluetooth depends on minimizing the maximum traffic load of nodes (thus minimizing the total power consumption of nodes). There are a lot more works on energy efficient communication in ad hoc wireless networks, such as in [13, 14]. The goal is to choose the transmit power level, so that low power levels can be used for intra-cluster communication and high power levels for inter-clusters. Some heuristic algorithms were proposed, namely the Broadcast Incremental Power (BIP), Multicast Incremental Power (MIP) algorithms, MST (minimum spanning tree), and SPT (shortest-path tree). The proposed algorithms were evaluated through simulations. So far, there is no published work that considers how to meet the overall QoS requirements through topology control. In this paper, we address the problem of topology control that can meet the QoS requirements and the total consumed power of nodes in the system is minimized.

3. System Model And Problem Specification

In this work, a group of notations will be used. We adopt the widely used transmitting power model for radio networks: $p_{ij} = \langle\, d_{i,j}$, where p_{ij} is the transmitting power needed for node i to reach node j, $d_{i\,j}$, is the distance between i and j, and $\langle$ is a parameter typically taking a value between 2 and 4. The network is modeled by $G = (V, E)$, where V is the set of n nodes and E a set of undirected edges. Each node has a bandwidth capacity B, and a maximal level of transmitting power P_{max}. The bandwidth of a node is shared for both transmitting and receiving signals. That is, the total bandwidth for transmitting signals plus the total bandwidth for receiving signals at each node shall not exceed B. Let p_i denote the transmitting power of node i. We assume that each node can adjust its power level, but not beyond some maximum power P_{max}. The connectivity between two nodes depends on their transmitting power.
From the network model, we can see that the network topology can be controlled by the transmitting power at each node and the topology directly affects the QoS provisions of the network. If the topology is too dense (*i.e.*, nodes have more neighbors), there would be more choices for routing, but the power consumption of the system would be high. On the other hand, if the topology is too loose (*i.e.*, with less edges), there would be less choices for routing (hence, some nodes could be over-loaded) and the average hop-count between end nodes would be high. Our goal is to find a balanced topology that can meet end-users QoS requirements and has minimum energy consumption. Let $\lambda_{s,d}$ and $\Delta_{s,d}$ denote the traffic demand and the maximally allowed hop-count for node pair (s, d), respectively. Let $P_{max} = \max\{ p_i \mid 1 \leq i \leq n\}$. The topology control problem of our concern can be formally defined as: given a node set V with their locations, $\lambda_{s,d}$ and $\Delta_{s,d}$ for node pair (s, d), find transmitting power p_i for $1 \leq i \leq n$, such that all the traffic demands can be routed within the hop-count bound, and *the total consumed power* is minimized. We consider one case, end-to-end traffic demands are not splittable, i.e., $\lambda_{s,d}$ for node pair (s, d) must be routed on the same path from s to d. We assume each node can transmit signals to its neighbors in a conflict free fashion. Thus, we do not consider signal interference in this paper.

4. Topology Control With Traffics Nonsplittable

Given:
- V, set of n nodes and their locations.
- B, the bandwidth of each node.
- $\lambda_{s,d}$, traffic demands for each node pair (s, d).
- $\Delta_{s,d}$, maximally allowed hop-count for node pair (s, d).
- P, maximally allowed transmitting power of nodes.

Variables:
- $x_{i,j}$, boolean variables, $x_{i,j}$ =1 if there is a link from node i to node j; otherwise, $x_{i,j}$ = 0.
- $x_{i,j}^{s,d}$ boolean variables, $x_{i,j}^{s,d}$ =1 if the route from s to d goes through the link (i, j); otherwise $x_{i,j}^{s,d}$ = 0.
- Pmax , the maximum transmitting power of nodes.

Optimize:
- Minimize the total transmitting power of nodes.
  Min *Total consumed power* (1)

Constraints:

- Topology constraints:

$$x_{i,j} = x_{j,i} \;\; if \quad \forall i, j \in V \qquad (2)$$

This constraint ensures that each edge corresponds to two directed links.
-

$$x_{i,j} \leq x_{i,j'} \;\; if \;\; d_{i,j'} \leq d_{i,j} \qquad \forall i, j, j' \in v \qquad (3)$$

- Transmitting power constraint:

$$p \geq p_{max} \geq d_{i,j}^{\alpha} x_{i,j} \qquad \forall i < j, i, j \in v \qquad (4)$$

- Delay constraint:

$$\textstyle\sum_{(i,j)} x_{i,j}^{s,d} \leq \Delta_{s,d} \qquad \forall\, (s, d) \qquad (5)$$

- Bandwidth constraint:

$$\textstyle\sum_{(s,d)} \sum_j x_{i,j}^{s,d}\, \lambda_{s,d} + \sum_{(s,d)} \sum_j x_{j,i}^{s,d}\, \lambda_{s,d} \leq B \quad \forall i \in V \qquad (6)$$

- Route constraints:

$$\textstyle\sum_j x_{i,j}^{s,d} - \sum_j x_{j,i}^{s,d} = \begin{cases} 1 \; if \; s = i \\ -1 \; if \; d = i \\ 0 \quad otherwise \end{cases} \quad \forall i \in V \quad (7)$$

$$x_{i,j}^{s,d} \leq x_{i,j} \qquad \forall\, i, j \in V \qquad (8)$$

- Binary constraint:

$$x_{i,j} = 0, or\, 1 \,, x_{i,j}^{s,d} = 0, or\, 1 \qquad \forall i, j \in V, (s, d) \qquad (9)$$

Constraints (8) and (9) ensure that the validity of the route for each node-pair. Since, traffics are not splittable, $x_{j,i}^{s,d}$ represents that the entire traffics of (s, d) go through link (i, j). The availability of bandwidth along the route is ensured by constraint (6). The problem of QoS topology control for nonsplittable has now been formulated as an integer linear programming problem (ILP) (1)-(10), which is NP-hard in general. In this work Matlab 9 is used to solve this problem.

5. The Introduced Constraint

The main objective of this work is to add a new constraint to the previous to affect the transmitted power consumption distribution. In other word, reduce the variance of the power matrix. The idea of this constraint is to force the system to use the minimum previous used nodes. So, it can just use the nodes which had consumed less than the average consumed power. The first problem with this constraint is that it tighten the system and find no solution specially in the beginning (the power matrix is zeros). In order to relax this constraint a threshold value is added to include more nodes above the average consumed power. Another problem is that the average in first request is zero which is equal to the transmitting power for all the nodes. So, this constraint is activated after three requests to avoid this problem.

$$P \leq P\,max + Threshold \quad \forall\ 1 \leq i \leq n \qquad (10)$$

The following sections discuss the optimum threshold value and a comparison between different threshold values, finally, a comparison between with and without this constraint.

6. Experiments

6.1 Simulation Setup

The simulations are conducted in a 30×30 two dimensional free-space region. The assumed number of nodes is set to be 15, for simplicity. The model is simulated to accept any number of nodes but with more time complexity. The co-ordinates of the nodes are randomly and uniformly distributed inside the region. All nodes have the same bandwidth capacity B = 500. The value of α in the transmitting power function is set to 2. The set of requests R={(s, d, $\lambda_{s,d}$)} are generated by using the Poisson function (i.e., the requests originating from a node follow the Poisson distribution). For each node, we use the random Poisson function with the mean value λ= 1 to generate a number k, which is the number of requests originating from this node. The destinations of the k request are randomly picked from the other nodes. The traffic demand $\lambda_{s,d}$ for a pair of nodes (s, d) is assigned by a random function of a normal distribution with variance equal to 0.5 μ_m , where μ_m is the mean value of the normal distribution function. Figure 1 shows the input chosen topology with number of nodes n=15 in 30×30 meter.
The model is simulated as an Integer Linear programming problem using matlab with the previous equation (1-10) include our new constraint.
The first issue for this fixed topology is to find the optimum threshold.

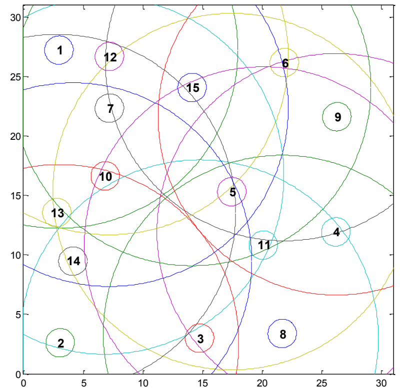

Figure 1 The input topology number of nodes n=15 in 30x30 meter

6.2 Simulation Results and Analysis

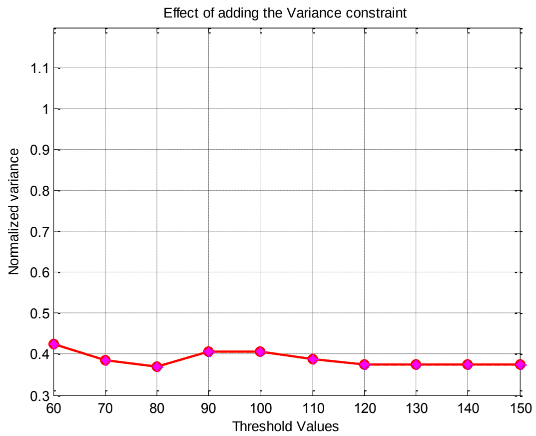

Figure 2 Effect of adding the Variance Constraints – Normalized Variance with the Threshold Value

We run this model ten times for each time different group of requests, each run is a time value T≈20 sec, in other words ***T1=T, T2=2×T, …, T10=10×T (T1 to T10)***. This is repeated for each threshold value as shown in figure 2, (60 to 150 with step 10, 10 values). Figure 2 depicts the minimum variance at threshold equal to 80. Also, it is noticed that the steady state occur at threshold equal to 120 or more.
Figure 3 illustrates a Comparison between with/without adding variance constraint. Almost 60% decrease of the variance by adding a threshold value. In another approach of analysis, the consumed power for n nodes after time nT, where n=1 to 10 and T=20 sec. During each T a group of requests occur. After each increment of T, the maximum/total consumed power among all the nodes is considered. Figure 4 illustrates the maximum consumed power with time for both cases (with/without the introduced constraint).
Figure 5 illustrates the total consumed power with time for both cases (with/without the introduced constraint). It is clear the effect of adding the new constraint which decrease the total/maximum consumed power.

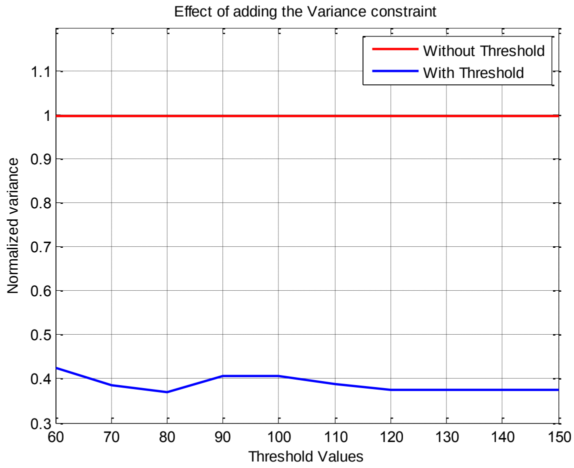

Figure 3 Comparison between with/without adding variance constraint

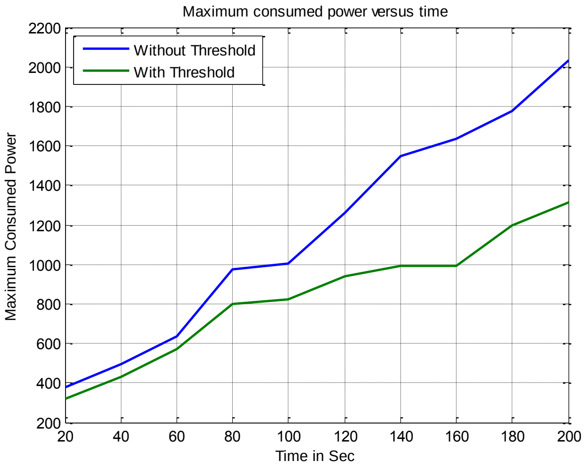

Figure 4 Maximum consumed power versus time

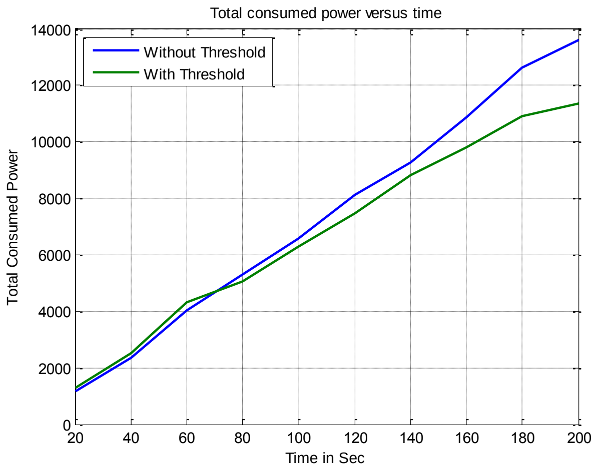

Figure 5 Total consumed power versus time

7. Conclusion:

The threshold constraint emphasizes a great effect on the routing decision. The variance is decreased compared with the model without the threshold value. The total/maximum consumed power is greatly decreased by more than 20%. The threshold value has an optimum value to be selected (80). It varies with number of nodes and the spread area for these nodes. The more dense of the network (increase of number of nodes), the more effectiveness of the introduced constraint which decrease the variance. In consequence this will extend the network lifetime.

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