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Effect of Topology Parameters Variation on AD-HOC Wireless Network Performance

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Abstract—a new approach is introduced for energy saving control problem in ad hoc wireless networks in this research. 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. The traffic demands are considered to be non-split. 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. This work discusses the effect of different network parameters on network lifetime. From the analysis the optimum bandwidth is 800 in this area (30m×30m) where number of nodes=18. Also, it can be concluded that the maximum consumed power is fixed with λm. Also, from the study, the introduced new constraint increase network lifetime and reduce the consumed power at any time with different traffic demands.

Keywords—Energy saving control, Quality of Service requirement, Routing in mobile ad hoc Network, Topology control.

I. Introduction

Wireless, or single-hop networks, was based on a fixed structure, basically network nodes communicating to fixed infrastructure [1]. An ad-hoc wireless networking offers multi-hop communication, in effect network nodes communicating via other nodes [2]. The idea of ad-hoc or packet radio networks has been under development since 1970s. Since the mid-90s, when the definition of standards such as IEEE802.11 (what we think of as WiFi or just 802.11) helped cause commercial wireless technology to emerge, ad-hoc wireless networking has been identified as a challenging evolution in wireless technology [3]. 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 [4]. 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. Extensive research has been done on QoS provisions in ad hoc networks, such as QoS routing or admission control. Most of the existing works deal with resource allocation (e.g., scheduling or buffering) or routing for QoS requests.

However, the construction of a network topology that can overall meet QoS requirements has not been studied in the literature. 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 [5]. 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. An ad hoc wireless network is a collection of information technology devices. It equipped with a transmitter and receiver, connected in the absence of fixed infrastructure. An ad-hoc wireless network is defined with unique characteristics over typical wireless networks [2]. Some of these characteristics are purpose-specific, autonomous, temporary, short range extended by use of multi-hop routing, heterogeneous / homogenous, minimal configuration, quick deployment, constrained devices, on line central Entity and dynamic. In comparison with fixed wireless networks, there is no master slave relationship that exists in an ad-hoc wireless network. Nodes rely on each other to established communication, thus each node acts as a router [4]. Therefore, in an ad-hoc wireless network, a packet can travel from a source to a destination either directly, or through some set of intermediate packet forwarding nodes. 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. Minimal configuration and quick deployment make ad hoc networks suitable for emergency situations like Natural disasters, Military Conflicts, Rescue operations, Vehicular communications, Sensing applications and Mesh networks [6]. The presence of a dynamic and adaptive routing protocol will enable ad hoc networks to be formed quickly. Wireless ad hoc networks can be further classified by their application into (mobile ad hoc networks (MANETs) or wireless mesh networks or wireless sensor networks).wireless ad hoc networks power control basically deals with the performance within the system. The intelligent selection of the transmit power level in a network is very important for good performance. Power control aims at minimizing the traffic carrying capacity, reducing the interference and latency, and increasing the battery life. Power control helps combat long term fading effects and interference. When power control is administered, a transmitter will use the minimum transmit power level that is required to communicate with the desired receiver [4]. This ensures that the necessary and sufficient transmit power is used to establish link closure. This minimizes interference caused by this transmission to others in the vicinity. This improves both bandwidth and energy consumption. However, unlike in cellular networks where base stations make centralized decisions about power control settings, in ad-hoc networks power control needs to be managed in a distributed fashion [7]. Routing in ad-hoc wireless network, meaning transferring packets from source to destination, is different than traditional routing in a fixed network. Routing in ad-hoc wireless networking depends on many factors which include topology, selection of routers, initiation of request and available bandwidth. In an ad-hoc wireless network, a packet can travel from a source to a destination either directly, or through some set of intermediate packet forwarding nodes. The topology of an ad hoc network can be controlled by some “controllable” parameters such as transmitting power [6]. Routing 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 (Routing control) 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 [8]. 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.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. Ad-hoc wireless networks are expected to play an important role in the deployment of future wireless communication systems. Therefore, it is extremely important that these networks should be able to provide efficient QoS that can meet the vendor requirements [6][11].

II. RELATED WORK

The earlier works of topology control can be found in [15]-[17]. 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. Distributed wireless systems (DWSs) pose numerous technical challenges. Among them, two are widely considered as crucial: autonomous localized operation and minimization of energy consumption. FarinazKoushanfar, et al. Address the fundamental problem of how to maximize the lifetime of the network using only local information, while preserving network connectivity. They start by introducing the care-free sleep (CS) Theorem that provides provably optimal conditions for a node to go into sleep mode while ensuring that global connectivity is not affected. They have also developed mechanisms for collecting neighborhood information and for the coordination of distributed energy minimization protocols. The effectiveness of the approach is demonstrated using a comprehensive study of the performance of the algorithm over a wide range of network parameters. Another important highlight is the first mathematical and Monte Carlo analysis that establishes the importance of considering nodes within a small number of hops in order to preserve energy [12]. Marwan Krunz and AlaaMuqattash, presented an overview of various power control approaches that have been proposed in the literature. We discuss the factors that influence the selection of the transmission power, including the important interplay between the routing (network) and the medium access control (MAC) layers. Protocols that account for such interplay also are presented [13]. AmeeshPandya and Greg Pottie presented a formulation that maximizes the non-communication application QoS (node motion to facilitate sensing) with communication QoS constraints (packet delay, etc.). It also gives the formulation for maximizing the throughput for the newly formed links at the new position of the node, taking link capacities into consideration. Each link is shared by multiple streams of traffic from different QoS classes, and each stream traverses many links. Although these formulations are non-linear, they can be posed as geometric programs, which can be solved efficiently [14]. Michael Barry and Sean McGrath outline some of the difficulties faced in providing QoS in an IP mobile ad-hoc networking environment. Pure IP solutions are shown to be inadequate without support from the underlying radio technologies. A network model is constructed where different elements of Ad Hoc networks and their influences on Radio Resource Management (RRM) and QoS can be investigated. These elements include Mobility, Aggregation, Channel Sharing, Statelessness, and

Routing. Each can be present to a greater or lesser extent in the network and will influence the RRM algorithms and overall QoS solution adopted [15]. Hung-Cheng Shih and Kuochen Wang presented a QoS-guaranteed energy-efficient packet scheduling algorithm for IEEE 802.16-2009 (WiMax) network interfaces. The integration of packet scheduling and sleep mode operation can make IEEE 802.16-2009-enabled mobile devices more energy efficient. Simulation results show that the packet scheduling algorithm has 14.37% less energy consumption than the naïve algorithm, and it does not sacrifice average packet delay [6]. Niranjan Kumar Ray and Ashok Kumar Turuk summarized most of Energy Efficient Techniques and suggested three energy efficient techniques to reduce energy consumption at protocol level. Efforts are made to classify these works in different category such as power management based, power control based, and topology control based. The first technique conserves energy by reducing number of route request message while other two techniques suggest different approach to achieve energy conservation [7]. SaikatGuha, PrithwishBasu, and Chi-Kin Chau Studied the problem of designing optimal sleep schedules in wireless networks, and show that finding sleep schedules that can minimize the latency over a given subset of source-destination pairs is NP-hard. They offered a novel solution to optimal sleep scheduling using green-wave sleep scheduling (GWSS), inspired by coordinated traffic lights, which is shown to meet latency lower bound (hence is latency-optimal) for topologies such as the line, grid, ring, torus and tree networks, under light traffic. For high traffic loads, they presented non-interfering GWSS, which can achieve the maximum throughput scaling law. Finally, they extend GWSS to a random network with n Poisson-distributed nodes [8]. Jian Ma, et al. presented both centralized and distributed solutions for QoS topology control, they employ the opportunistic transmission to catch the best transmission opportunities on transitional links. The simulations demonstrate that opportunistic transmission based approach can significantly improve energy-efficiency in QoS topology control with low communication overhead [9]. IEEE 802.11 is a standard for wireless local area networks. Recent works show that this standard has bad performances in ad-hoc mode. Berqia, at el. Analyzed the algorithm used by the standard to manage contentions and presented an alternative algorithm to resolve fairness issues observed in the Hidden terminal scenario, Using NS-2 simulator. The final results shows that the presented algorithm has better throughput management based on fairness between nodes under QoS constraints required by each node [10]. Jang-Ping Sheu, et al. presented a distributed protocol that deals with topology control at the network layer and at the same time overcomes the hidden terminal problem at the MAC layer. Each node in the networks determines its power for data transmission and control packets transmission according to the received beacon messages from its neighbors. The presented distributed protocol works without location information and use little control packet overhead to prevent potential collisions due to hidden terminals. Simulations show that the protocol significantly decreases the total power consumption in the networks and has a better network throughput compared to other protocols [11]. 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.

III. 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 $P_{max} = \max\{p_i \mid 1 \le i \le n\}$. 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 $1 \le i \le n$, 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.

IV. Methodology

All the simulation is done using Matlab. The first selection for our simulation is the number of nodes n. Second step is to distribute the nodes randomly in any specified rectangular region, the nodes are represented as a circles. The problem solver is based upon Integer Linear Programming. The objective function is minimizing the total consumed power subject to the constraints defined in the next subsections. Our method is new because of our new constraint. The figures compare between with and without threshold. Non-Split is the only considered case. One main advantage of the proposed model is the dynamicity. All the parameters are assumed to be changeable such as Traffic demand λ_m, number of nodes n, and Bandwidth B.

V. 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 routefrom 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:

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

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

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

- Transmitting power constraint:

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

- Delay constraint:

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

- Bandwidth constraint:

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

- Route constraints:

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

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

- 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 10 is used to solve this problem.

VI. 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.

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

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

VII. Experiments

A. 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 $\mu_m$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.

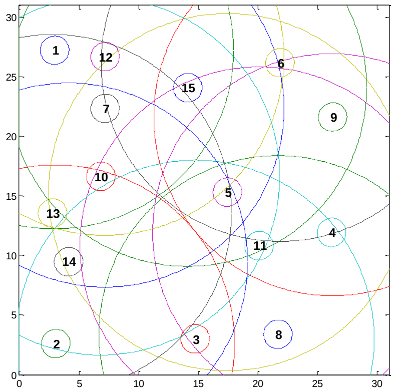

Fig. 1 The input topology number of nodes n=15 in 30x30 meter

B. Simulation Results and Analysis

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)***.

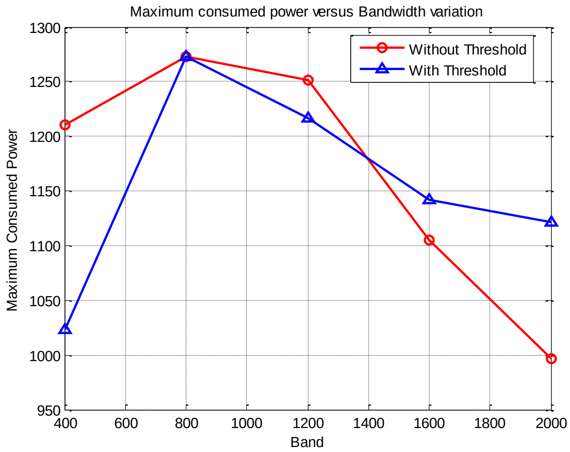

Fig. 2 The effect of bandwidth for maximum consumed power

Figure 2 illustrates the effect of bandwidth variation on the maximum consumed power, actually the bandwidth has no fixed waveform but with this area and distribution, the optimum bandwidth value is 800.

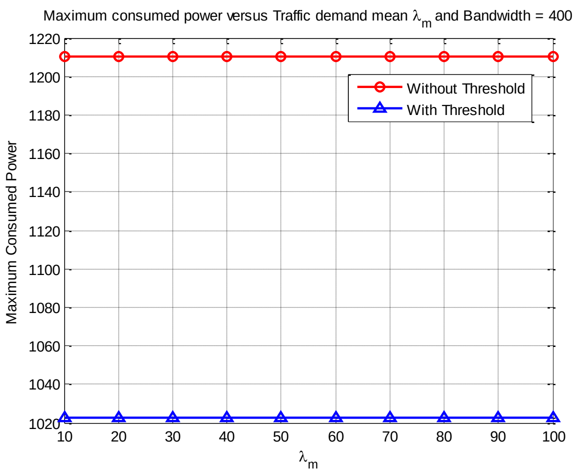

Fig. 3 The maximum consumed power variation with the traffic demand mean value λm with and without threshold constraint.

In figure 3, it is obvious from this figure that the maximum consumed power is fixed with λm. The reason behind this is that the nodes are fixed. In the meanwhile, the threshold constraint obviously reduces the consumed power.

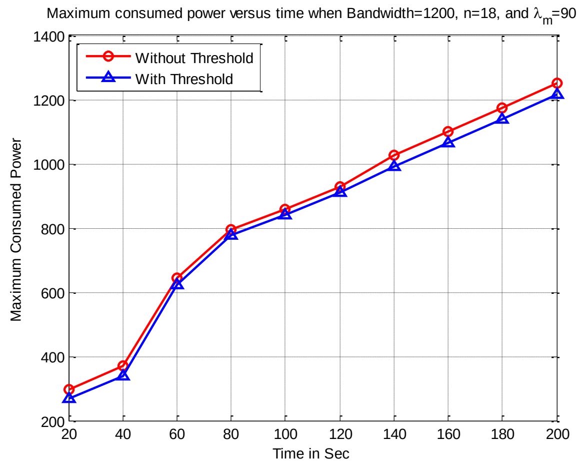

Fig. 4 The maximum consumed power variation with the time (with and without threshold constraint).

Figure 4 illustrates the maximum consumed power with and without threshold constraint at specific λm = 90, and bandwidth = 1200. From this figure, it is concluded that the threshold constraint increase the network lifetime.

VIII. ALGORITHM

A. Preprocessing:

a. Prepare the topology for each number of nodes, say for n=6, 8, 10, 12, 14, 16, 18, and 20 using random selection of location using uniform distribution.
b. For each node i, i varies from i= 1 to n, there is a group of neighbor nodes defined according to the range of communication around each node (circle around each node).
c. The neighbors for each node i are defined by range and angles with respect to the node i.
d. For each topology generate the associated group of requests using Poisson distribution with the defined parameters before for each value of λ_m for each request a value λ_{sd}, where s is the source, and d is the destination.
e. Now, for each topology, there are a group of requests associated with each value of λ_m.

B. Simulation

a. Select a value n, for this value use the defined topology, calculate the distance matrix d_{ij} where i,j varies from 1 to n, and d_{ij} is the distance from node i to node j.
b. Select a value for λ_m and a value for the bandwidth=500, and a group of threshold values.
c. Repeat the following for each value of λ_m and value of threshold (nested loop).
   i. Repeat a sequence of runs with the previous fixed values to simulate 10 periods of time T.
   ii. For each run do the following:

1. Pick thefirst request from the generated before.
2. Generate the power vector using the distance matrix.
3. Define the objective function (minimize the total consumed power).
4. Simulate the defined equations of constraints in a matrix form as function of n values.
5. Solve using Integer Linear Programming.
6. Repeat for all threshold values for each request.
7. Repeat for all requests.

d. Save all the results with the defined parameters in a structure array to use in the analysis.

IX. 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. From the analysis, that the maximum consumed power is fixed with λm. The reason behind this is that the nodes are fixed. In the meanwhile, the threshold constraint obviously reduces the consumed power in all the steps of the network lifetime. The maximum consumed power is reduced clearly (almost 10%) with the introduced threshold constraint compared with the original model. This results in increasing the network lifetime.

X. FUTURE WORK

The need of real implementation of the model and comparing the proposed theoretical model with the practical one is the first topic for future trend. Adding split demand will add another complexity because it makes the problem transferred to Mixed Integer Linear Programming. Currently, the group is working in these issues.

XI. REFERENCES

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