FIREWOKS
An Efficient Location Based Searching Scheme In Ad Hoc Networks

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Abstract

Searching and routing in ad-hoc network are important procedure to ensure data transmission due to the lack of fixed infrastructure. However, naïve-flooding searching is too expensive and takes considerable amount of valuable bandwidth in ad-hoc network. People start thinking to exploit localized information that can aid searching and routing in ad-hoc networks. In this report, we present a novel position based searching scheme ---so called Fireworks --- in ad-hoc networks. We showed that the scheme is working and reliable, while reducing the searching overhead greatly. The Fireworks scheme is implemented and comparisons in a variety of parameters between fireworks and simple flooding schemes are shown in this paper.

Keywords: Ad Hoc Network, Position Based, Routing, Searching, Fireworks

1. Introduction and Motivation

Ad Hoc Networks are basically networks on demand. In other words, ad hoc networking allows an arbitrary collection of mobile nodes to create a network whenever needed. There is no infrastructure provided and mobile nodes are responsible to form a network when they come close enough to each other. Here close enough means they should be within the range of each other. Each node may act as source, destination and relay.

When a node tries to reach another node, the easiest way to do that is flooding. But, using flooding extremely increases the network overhead and wastes the bandwidth. Also another concern is that wireless devices are restricted to battery power. They must use their energy efficiently both for themselves and the network life. Notice that it is not enough to minimize the total energy used, but we also have to distribute the power consumption well. If one node is repeatedly used as a relay or a source, its battery may die fast. The whole MANET may be disconnected quickly by this way. So Expanding Ring Search for a particular node or Flooding are not good ideas. Briefly, reaching a node must be more efficient in terms of power consumption and also we should not disturb whole of the network.

Although routing/searching in MANET is not an easy thing to do, we are not totally hopeless. In a lot of cases, we have some location information of the destination, although not accurately. We may exploit the location awareness in favor of routing or searching in MANET. Therefore, we propose FIREWORKS, which is expected to cover as much nodes as possible with the minimum disturbance of the network and optimum distribution of power consumption.

FIREWORKS model first appeared in the concept of searching in wired peer- to- peer network. There, a message randomly walks among the nodes in the network until it reaches some interesting point (such as a cluster), and then it explodes. It is claimed that it is much more resource saving than simple flooding, and it is scalable.

Our FIREWORKS model works almost the same way it does in wired peer-to-peer network. We found it is scalable, and it is a potential solution to some of the difficulties we mentioned earlier in ad hoc network.

In the next section, we will briefly review the previous work in this area. And then we will introduce our algorithm, FIREWORKS, and explain how it works in details.

2. Related Work

DREAM

In DREAM the sender S of a packet with destination D will forward the packet to all one-hop neighbors that lie in the direction of D'. In order to determine this direction, a node calculates the region that is likely to contain D, called the expected region. As depicted in Figure, the expected region is a circle around the position of D, as it is known to S. Since this position information may be outdated, the radius r of the expected region is set to (t_1-t_0) Vmax, where t1 is the current time, t0 is the timestamp of the position information that S has about D, and Vmax is the maximum speed that a node may travel in the ad- hoc network. Given the expected region, the direction towards D for the example given in Figure 9 is defined by the line between S and D and the angle. The neighboring hops repeat this procedure using their information on D's position. If a node does not have a one-hop neighbor in the required direction, a recovery procedure has to be started. This procedure is not part of the DREAM specification.

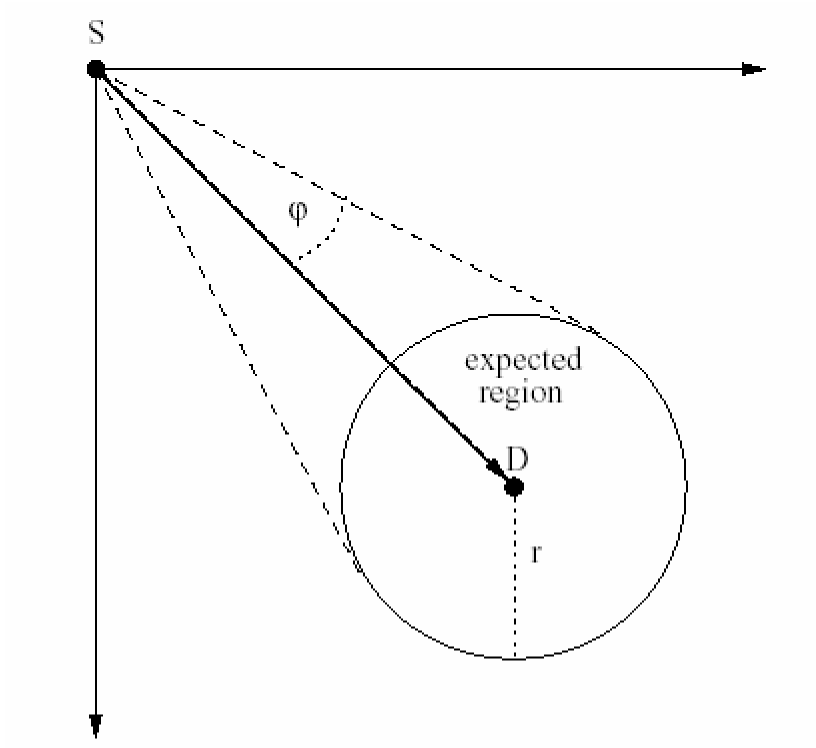


Figure 1 - How DREAM works

Location Aided Routing (LAR)

The Location Aided Routing proposal [19] does not define a location-based routing protocol but instead proposes the use of position information to enhance the route discovery phase of reactive ad-hoc routing approaches. Reactive ad-hoc routing protocols frequently use as a means of route discovery. Under the assumption that nodes have information about other nodes' positions, this position information can be used by LAR to restrict the flooding to a certain area. This is done in a fashion similar to that of the DREAM approach. When node S wants to establish a route to node D, S computes an expected zone for D based on available position information. If no such information is available LAR is reduced to simple flooding. If location information is available (e.g., from a route that was established earlier) a request zone is defined as the set of nodes that should forward the route discovery packet. The request zone typically includes the expected zone. Two request zone types have been proposed in [19]: The first type is a rectangular geographic region. In this case, nodes will forward the route discovery packet only if they are within that specific region. This type of request zone is shown in Figure. The second type is defined by specifying (estimated) destination coordinates plus the distance to the destination. In this case, each forwarding node overwrites the distance field with its own current distance to the destination. A node is allowed to forward the packet again only if it is at most some δ (system parameter) farther away than the previous node.

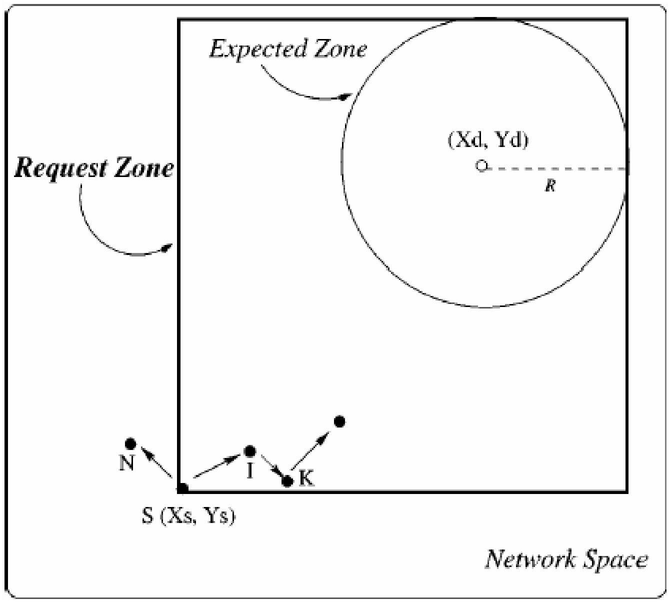


Figure 2 - How LAR works

3. FIREWORKS Scheme

In our scheme it is assumed that GPS (Geographic Positioning System) and 5-hop neighborhood information is available. So, each node has the information of own and 5 neighbors' locations. If we know, at least approximately, the direction of destination node, we can use an angle in order to go in that direction. We can gather this information from our previous transmissions to that node or maybe we have the information of our 5-hop neighborhood. Nodes that receive the message can compute their angle with respect to the source node and if they are within a threshold angular value of the specified angle then they re-transmit the message. If not, they ignore it. So, this kind of transmission may be referred as "directed broadcast". The visual approximation of this may look like a pizza slice. It is seen that, after a transmission made, only the nodes within a certain angle range take responsibility of re-sending it, so we don't bother the other parts of the network. Things to consider: we should specify the distance, i.e. how far should we go to that direction, secondly, should we adjust our power range, is it required or not, and finally determination of threshold angular value may affect the performance.

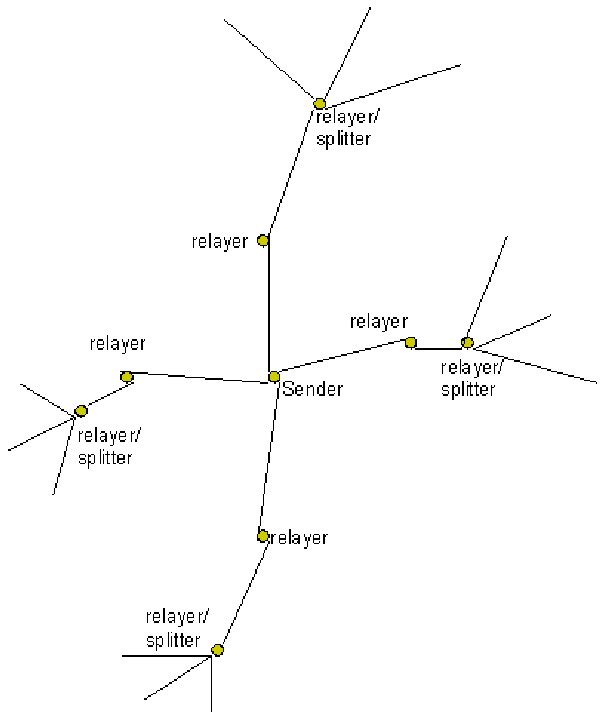


Fig 3: An Overview of Firework

The above figure shows the basic operations in Firework. In that example, the sender wants to search for a particular node in the network, so it sends out probes for four directions. The probes may be relayed and extended by relayers. When probes reach a certain number of hops, it will explode and split into several more probes each. The procedure repeats until all probes reach max number of hops. By this way, probes will be sent to all corners of the network and hopefully it can find the target.

To ensure the probes will continue on their direction, a concept of “relay zone” has to be defined here. A relay zone is a piece of “pizza slice” (shown in the next graph) inside the power range. The size of a relay zone depends on the power range and the threshold angle. By only allowing nodes inside the relay zone to relay (all nodes outside relay zone are not permit to relay, although they may hear the broadcast.), the direction of a probe will be kept.

Ideally, we would wish only one node in a relay zone to broadcast, since the extra broadcasting will not increase coverage and it will intensify the contention of the ad hoc network.

Now we introduce our broadcast suppression mechanism. Each node which receives broadcast command will not broadcast immediately. Rather, they are delayed a certain amount of time before they broadcast. Since the delay time is different from each other, the node which broadcasts first will suppress pending broadcasts in other nodes in the same zone. Thus, ideally, only one node in a relay zone will broadcast.

How to pick a good candidate for relayer is a selection problem. Normally solutions require synchronization of clocks among the nodes. Actually we want to find a node furthest to the sender and closest to sending directions. So we use the following metric D:

d1: distance to the direction of the zone

d2: distance to the edge of power range

$$D = d1 + d2$$

Each node will set its broadcast delay proportional to D, so the node which furthest to the original sender and closest to sending direction has the shortest delay to send. The node which broadcasts first will suppress the rest in the zone. Note that nodes in one zone will not cancel broadcast in another zone.

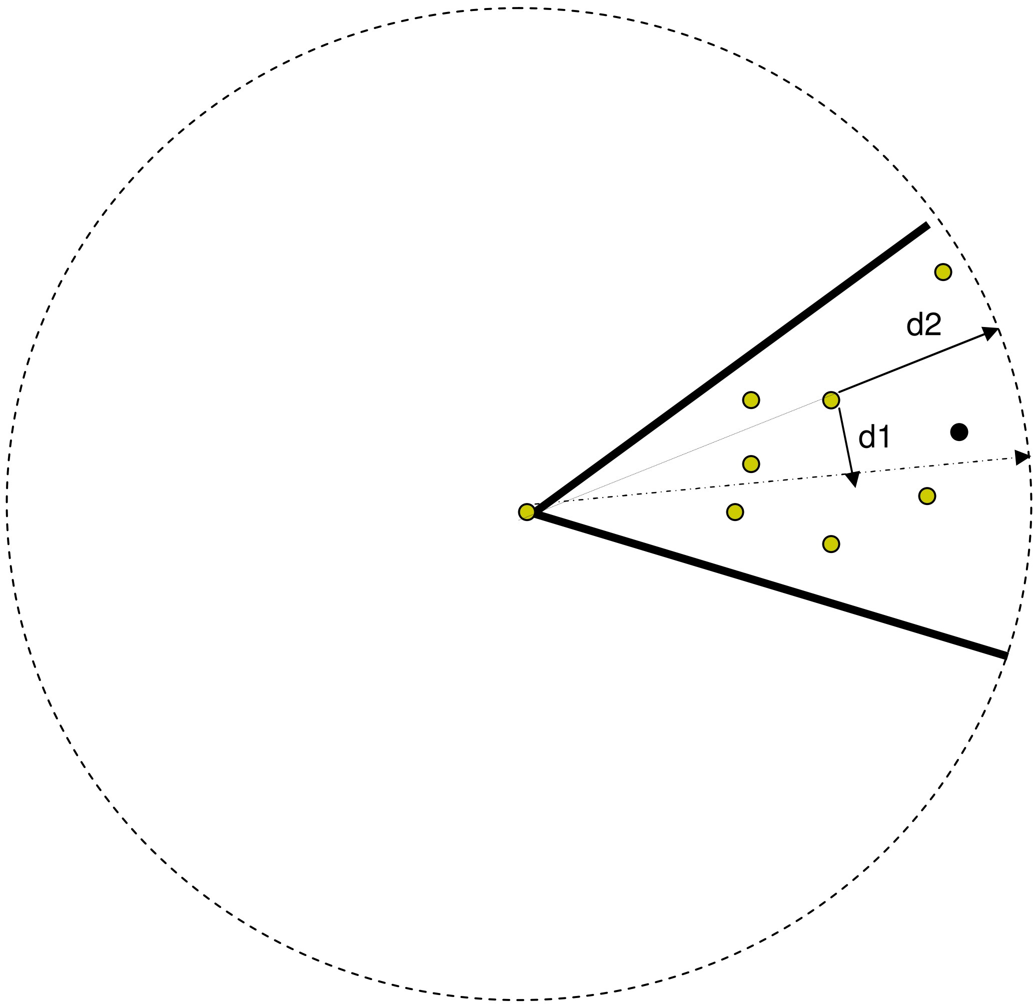


Fig 4 Relay Zone and Broadcast Suppression.

4. Performance Comparisons

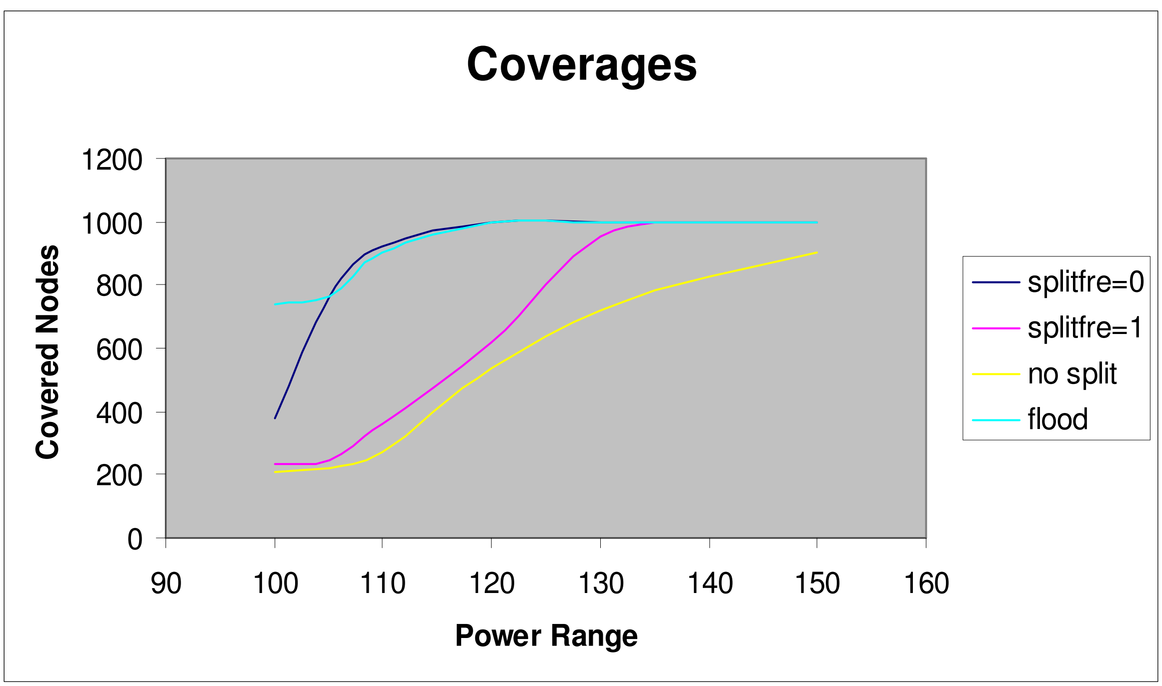
Our simulation environment consists of 1000 nodes in a 2000 by 2000 square area. The sender is in the center of this area and initiates the transmissions among the nodes. For locality information, we used 5- hop neighborhood. So each node knows its nearest 5 neighbors. In order to terminate a transmission we used maximum number of hops, so that when the number of hops reaches their maximum value, that transmission is cancelled.

The Firework scheme uses split frequency in order to decide in which steps to make a burst and divide the probe into several probes. No split means, the probe does not make a burst till it reaches to maximum number of hops. If the split frequency is 0, then the probe bursts at each hop. When the split frequency is 1, it means the probe bursts every second hop.

Deciding performance metrics was another challenging issue. We used coverage, contention and efficiency, in terms of covered nodes over total number of broadcasts. Each metric will be explained in more detail in the following sub-sections.

4.1. Coverage

In our simulation, we used various transmission power ranges and for each of them we calculated the number of nodes reached.

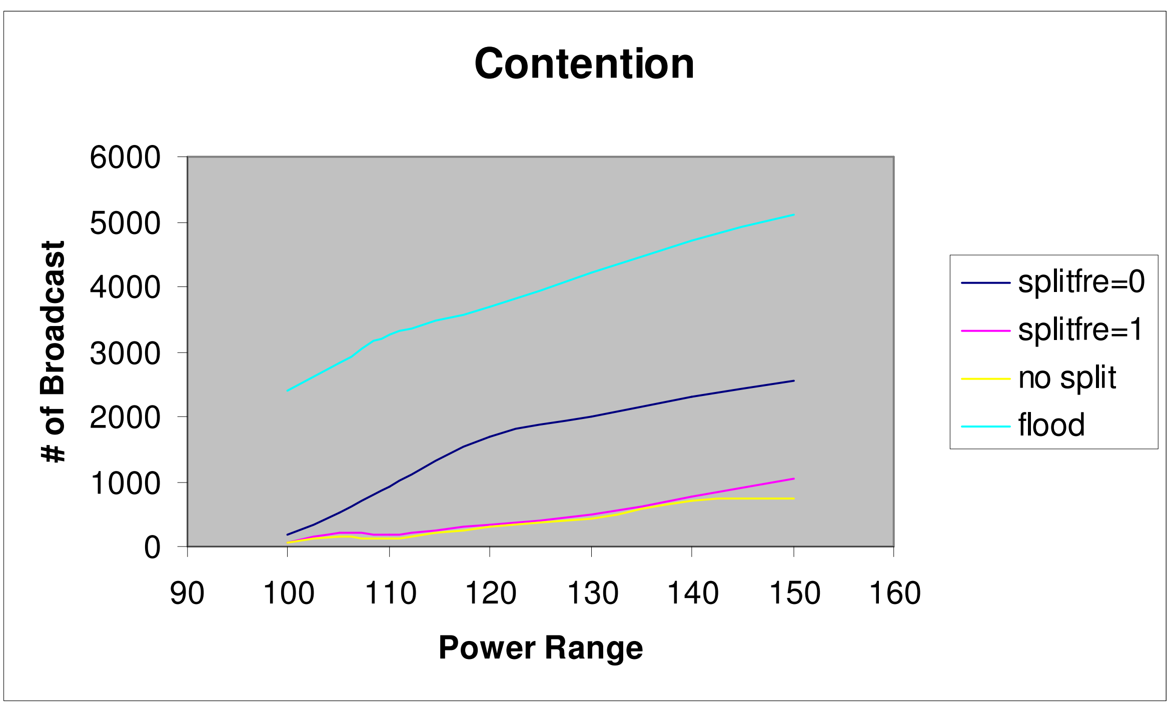


Number of nodes covered is strongly related to the power range used. But of course after a certain power range, the curves become flat as the power range increases, since all the nodes are being able to be covered from then on.

In the sense of coverage, flooding beats our algorithm. Even in a very small power range, i.e. 100, it covers much more than Firework algorithm. But notice that the Firework algorithm with split frequency 0, reaches rapidly to the coverage of flooding. They cover all the nodes with the same amount of power range. With the other split frequencies, our algorithm covers all the nodes by higher power ranges, and the increase is slower.

4.2. Contention

The main overhead of all of the routing protocols is the contention, which is strongly related to the total number of broadcasts. Hence we used different power ranges to calculate the total

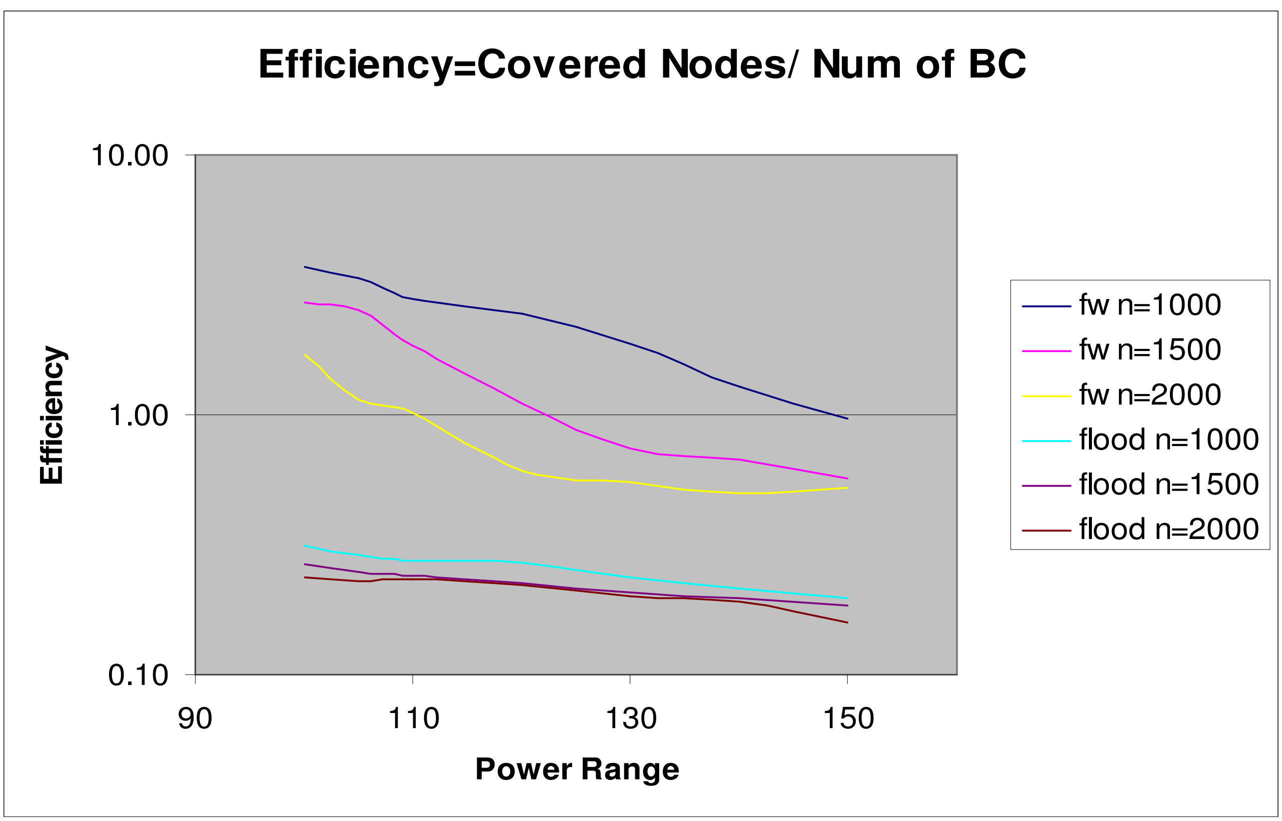


number of broadcasts made by flooding and our algorithm.

It is clear to see that flooding lost the advantage earned in the previous sub-section by covering more nodes even with small power ranges. The total number of broadcasts greatly increases as the power range increase in flooding. The Firework algorithm with the split frequency 0 has comparably high number of broadcasts than other schemes with different split frequencies. But again it is much better than flooding. The other schemes of Firework algorithm, with no splitting and splitting every second hop, have a very small total number of broadcasts even in high power ranges.

4.3. Efficiency

Now, it is time to look at the efficiencies of flooding and Firework algorithm. The efficiency is calculated by dividing the number of nodes covered by the total number of broadcasts made using a certain amount of power range. We examined the situation with different power ranges.



By looking at the graph, we can easily say that our algorithm does much better than flooding. By using relay zone, and going through a certain direction, it reduces the total number of broadcasts drastically. By this way even with high power ranges, it does not lead to network overhead while covering all the nodes.

As the total number of nodes increases the performance of the algorithm reduces due to the increasing number of broadcasts made. But still, its difference with flooding is remarkable. Also considering that the y-axis values are log based, and then we can see Firework algorithm is far better than flooding.

5. Conclusion

In this work, we designed the Firwork searching scheme, and show it has good performance. Firework can have the same coverage as flooding, while being more efficient in terms of number of broadcastings. We show that there is no too much difference between splitfre=1 and splitfre=(infinity) in terms of coverage. So we can always use splitfre=0 or splitfre=1, depending on the trade offs between coverage and contention. We also introduce the concept of relay zone and designed a mechanism of suppressing multiple broadcasting in a single relay zone. The mechanism is effective and does not require global clock synchronization as previous work does. Firework graph is easier to get disconnected than flooding graph, because firework generally has smaller angle of relaying zone than simple flooding (in which relay zone angle is 360 degrees). However, multiple tries can compensate the problem. Firework could be even more effective if we reduce the number of tries, but it will suffer the loss of coverage when num of neighbors becomes too small.

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