

# Interference Reduction in Wireless Networks

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## Abstract

The presence of interference in wireless networks is quickly being focused upon as a problem in today's world. Unfortunately, research is so young that leading researchers have differing ideas regarding the identification of a universal measure of network interference. But some goals have become cemented as necessary, such as the requirement of a low interference network that does not sacrifice other aspects of a network and maintains overall network performance. One proposed methodology of interference reduction is through topology control, which seeks to establish a strong network while still keeping the interference generated at a minimum. In this paper, we discuss existing topology control algorithms and present open problems to spur on active development of interference reducing network solutions.

## 1. Introduction

With the growing concern of a shrinking world and the advancement of modern technology, the use of wireless networks has spread rapidly over the last few years. From that growth, the threat of an interference-induced loss of quality in wireless networks is becoming more imminent. Interference, caused by multiple transmission signals being sent simultaneously over a shared radio frequency, induces a loss of data being sent over a network. Due to interference, the packets of data sent over wireless networks become lost and never make it to their destination, requiring more time and energy sent to resend the packets until they reach their final destinations. Research is currently under way to attempt to find ways to reduce wireless network interference, and allow for a continued use of wireless networks without worry of a future where such technology will be rendered ineffectual. This research is performed through topology control, a way to structure network placement and signal transmissions in a given area in order to minimize the interference in that area. Before reducing interference in an area, however, interference must be measured so that we can tell how much of an improvement is made using a particular method of reduction.

## 2. Measurement of Interference

Interference is typically measured in two ways, traffic-based and traffic-independent. Most uses of topology control define interference as "traffic-based interference," or measured in the airspace of a network through the number of overlapping signals of the same frequency and their effect on surrounding nodes. Since traffic-based interference is application-dependent, "traffic-independent" interference measures have been developed. According to Pascal von Richenbach et. al [2], the only

way to accurately define and view interference is looking at topologies with traffic-independent measurement in mind. Such models depend on the network topology only.

The most common (and simpler) topology is the Unit Disk Graph (UDG), with wireless senders and receivers as vertices (also called nodes), and edges connecting pairs of nodes that can communicate directly with each other.

One particular interference model is the sender-centric model, which considers interference as an issue at the sender's location. Claiming that such a model does not reflect upon real world interference very well, receiver-centric model was formed, which defines interference as the number of nodes that contain another node (the receiver in this case) within their communication range. The reasoning behind this is that the sender does not actually experience the interference when sending the signal, and that the receiver is subject to a poor quality reception due to interference.

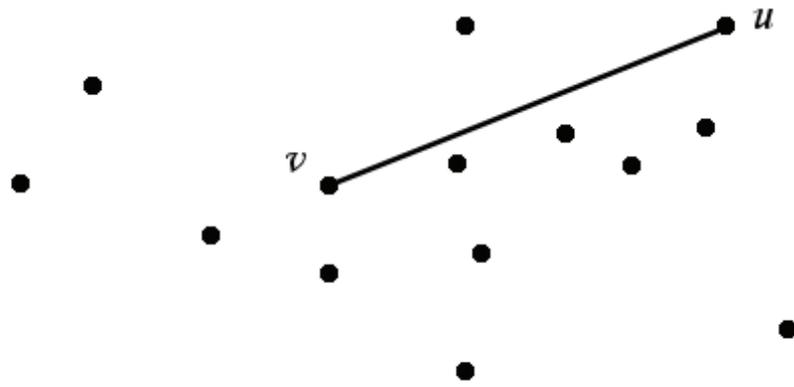
In light of debates regarding a universally agreed upon system of interference measurement and definition, algorithms addressing interference reduction state the measure of interference that is being used. This freedom from a particular measurement constraint, however, allows more potential solutions to be developed.

### 3. Methods for Reducing Interference

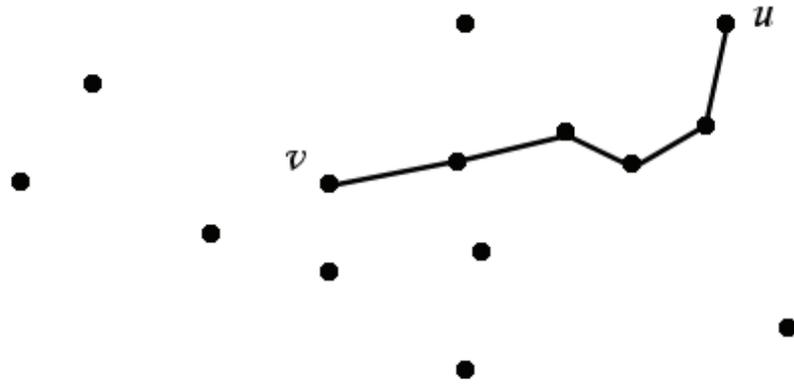
Currently, the field of wireless interference reduction is young, and research scant. This lack of much background work has allowed for a multitude of perspectives to be taken towards interference reduction. A common flaw according to Rickenbach [2] is that the vast majority of interference-reducing algorithms concentrate on simply reducing the number of links in a network, believing that with fewer signals present the interference will "sort itself out." This idea, however, is not the most effective at generating a lower interference. Similarly, Burkhart [1] [3] claims that the maximum degree in a network serves merely as a lower bound for the network's interference. From this, it can be concluded that algorithms that concentrate on reducing interference through methods other than simply reducing the degree of nodes in a network should be sought after.

While some algorithms do attempt to follow these declarations, the vast majority still adhere to the older, more basic target of link reduction. The end goal of earlier algorithms centering on link reduction is to find a balance between network interference present and the time and power used to reduce interference further. While there are ways to reduce interference significantly, these may come at the cost of draining large amounts of power or overly long time taken to generate the topology. While these methods may generate a significantly interference-light network area, the means taken to implement them are too costly to justify the results.

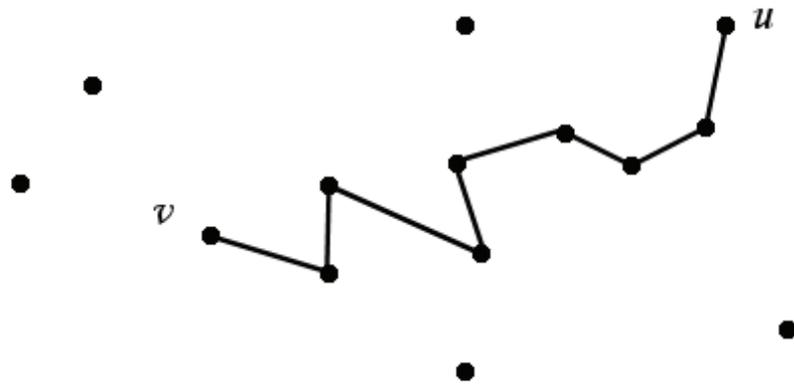
Figure 1 demonstrates an example network where node  $v$  connects to node  $u$  directly, which would cause interference at all nodes that lie within the disk centered at  $v$  of radius  $uv$ . Figure 2, on the other hand, shows this same situation, only with node  $v$  using intermediate nodes to access node  $u$  while generating significantly less interference. Figure 3 shows an example that uses too many links between two nearby nodes to justify the resulting reduced interference. With this balance as a goal in mind, several different topologies have been developed.



**Fig. 1. A high-interference topology with directly connected nodes.**



**Fig. 2. A low-interference topology network utilizing intermediate shorter links in place of a long link.**



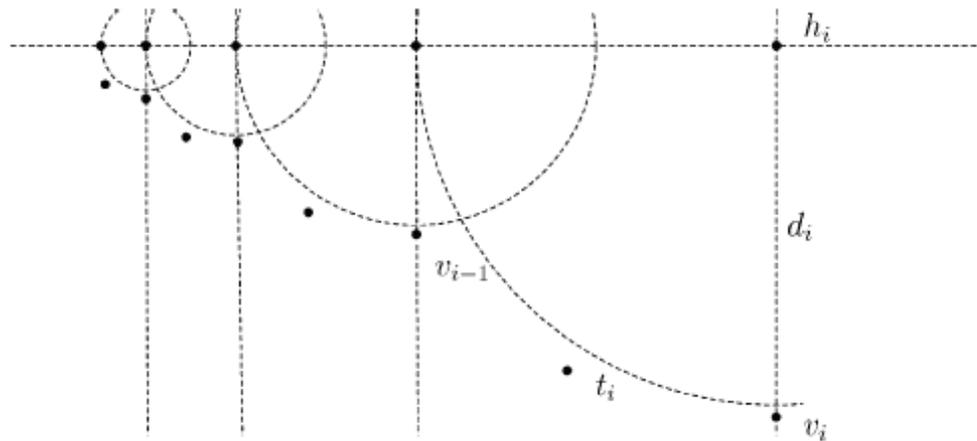
**Fig. 3. A topology using too many intermediary nodes to justify a reduced interference.**

#### 4 Algorithms

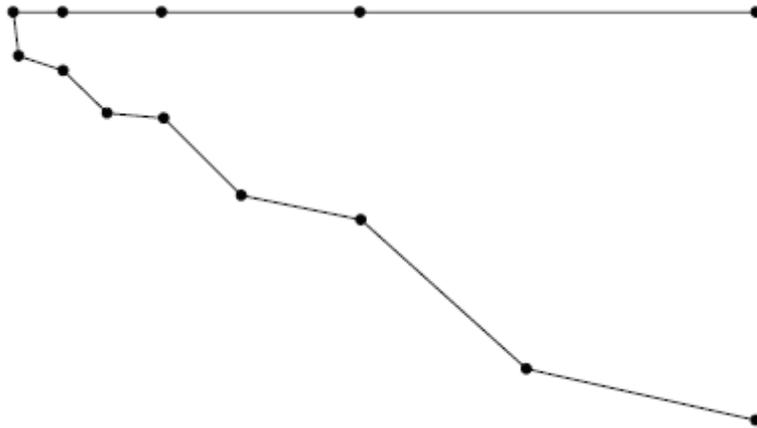
One question that is still very much in theoretical stages is what topology control algorithm to implement to obtain the optimal interference in a given network, while still preserving its connectivity. Connectivity is defined as the ability of one wireless node to communicate with any other node. All current algorithms require wireless nodes to extend their transmission range to a specific length, in efforts to establish connections between nodes without the wireless signal going any further than necessary and causing interference at other nodes.

##### 4.1 Greedy Algorithms

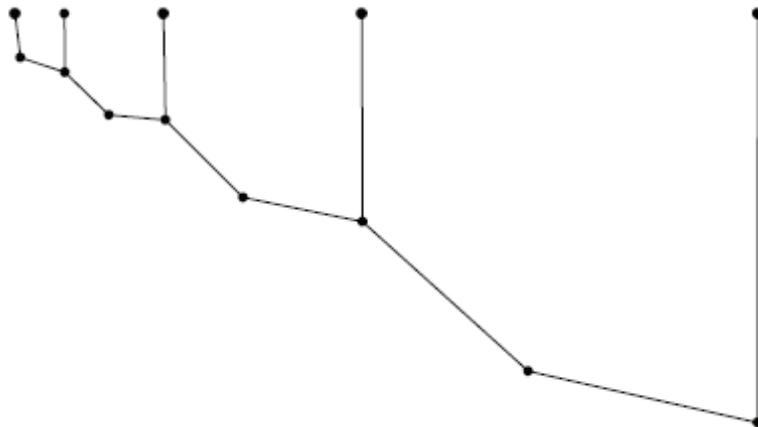
A very simple topology control algorithm would require nodes to perform a search of their surrounding area and establishing a connection with the closest one. While this “greedy algorithm” successfully reduces interference, Wattenhoffer [4] shows that it does not generate optimal interference for a network. An example in which such an algorithm performs relatively poorly is an exponential node chain, which is covered in Section 4.2.



**Fig. 4. A network where the greedy algorithm does not yield optimal interference [1].**



**Fig. 5. The closest-neighbor method for this two exponential node chain example produces interference  $O(n)$  [1].**



**Fig. 6. The same node set as in Fig. 5, connected in optimal interference topology [1].**

Wu and Liao [5] developed algorithms that improve upon this greedy algorithm. The work of Wattenhoffer, Wu, and Liao demonstrates that the low-interference topology control problem is indeed very difficult, and in light of this, algorithms for special network topologies, such as the exponential node chains, have been developed.

#### 4.2 Exponential Node Chains

Topology algorithms for reducing receiver-centric interference are those designed around the “exponential node chain,” a topology of nodes that are placed in a straight line with the distance between each pair of nodes growing exponentially longer. A baseline algorithm used in such topologies connects each node with its closest neighbor (Fig. 4). Due to the increasing amount of overlapping signals, this algorithm results in  $O(k)$  interference at the  $k$ th node from the left, or  $O(n)$  interference overall. Another network example consisting of two exponential node chains, shows that connecting each node to its closest neighbor (see Fig. 5) results in  $O(n)$  interference, however the optimal topology (as depicted in Figure 6) has constant interference. Rickenbach [6] improves

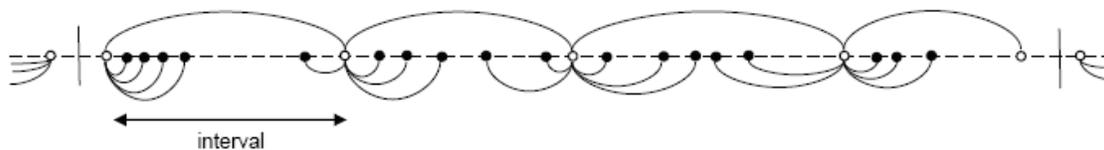
upon this baseline algorithm by developing a clever algorithm that results in  $O(\sqrt{n})$  interference, which is optimal for the exponential node chain (displayed as in Fig. 7). The degree of each node in this topology is  $O(\sqrt{n})$ .



**Fig. 7. Pascal von Rickenbach’s logarithmic exponential node chain topology [6]. Here, each hollow node is a hub and is connected to every other node, as well as their nearby hubs.**

### 4.3 The Highway Model

A generalization of the exponential node chain is the Highway Model, a linear topology where the nodes are not necessarily arranged so that the distance between each pair is exponentially longer than the last. Although this model topology seems rather simple, approximation solutions for this model are fairly complex, and optimal solutions are yet to be developed. Rickenbach [6] has proposed an approximation solution that employs a decomposition of a “highway” into multiple exponential node chains and uses the optimal algorithms designed for such chains. The algorithm employs virtual nodes that will later be adjusted so the signals to the virtual nodes can translate to the true nodes present. Another solution proposed by Rickenbach [2] involves the highway to be split into segments of equal length, with certain nodes designated as hubs. These hubs will connect to each other in a linear fashion, as other nodes connect to the nearest hubs, as in Figure 8. If the largest number of exponential node chains in a segment is  $k$ , the resulting topology has  $O(\sqrt{k^3})$  interference.



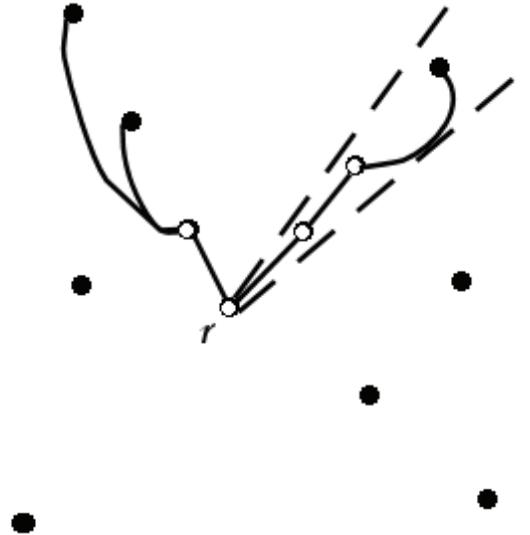
**Fig. 8. Rickenbach’s second proposed solution to the Highway Model [2]. Each hollow node is a hub, and each node is connected to its nearest hub.**

### 5. Proposed Work

We propose to expand upon previous algorithms designed for exponential node chains so they may be usable in a two dimensional topology. The difficulty of forming such an algorithm is the reason why little to no research on making more universally applicable exponential node chain algorithms has been conducted.

Plans for the development of an exponential node chain algorithm so that it may function in two dimensions utilize sectioning off the surrounding area of an arbitrarily chosen root node of a topology. Once the root is designated, a cone-shaped signal will be

sent from the root node, incrementing itself around the node so that no two sections overlap. At most, there will be three hundred and sixty sections around the root node, assuming each section is set for one degree of width. The signals will perform exponential node chain construction within the current section, with the root node of the network acting as the chain's root, and then perform an interference analysis of the resulting topology.



**Fig. 9. Root node  $r$  sends constructs an exponential node chain of the topology within the current section denoted by the dotted lines. Following Figs. 7 and 8, each hollow node is a hub, and each node is connected to its nearest hub.**

The work on such an algorithm is projected to take up to two months of time. The first week will be spent concluding all current research on wireless network interference reduction. The following two weeks will be used to determine topologies that can be simulated for this algorithm with programs such as the free QualNet [7]. The following three weeks will be spent developing the algorithm, as well as testing the algorithm's implementation and performance. The final week will be centered around refining the algorithm in order to produce the most efficient and quickest result, while still ensuring the best possible interference in a wireless network.

## 6. Conclusion

This paper reviewed some of the currently existing methods designed to reduce the interference present in wireless networks. Through an overview of both current and past research, the groundwork has been laid for the formation of a new algorithm designed to improve upon the current Exponential Node Chain algorithms. The future of interference reduction has many open questions requiring answers, but appears that there is promise due to the growing concern of interference's existence in a technologically growing global society.

## Sources

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