Topological Design of a K-Connected Communication Network

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Abstract: - The goal of topological design of a K-Connected wireless communication network is to achieve a specified performance at minimal cost and delay. Unfortunately, the problem is complexity intractable Steiglitz, Winner and Klietman have presented an optimal algorithm for generating a potential network topology. In this paper we present first, an optimal method for generating a K-connected network when the number of nodes is exactly equal to 2^K. Secondly, the heuristic begins by numbering the nodes at random. This paper presents a systematic method for numbering the nodes when the nodes (assumed even in number), all lie on a straight line, are equispaced and the connectivity that is sought is even. Assuming that the cost of a link is proportional to its length, the method presented has been found to give the cheapest starting network. When the nodes are numbered in a systematic manner, the potential network topology requires minimum perturbation before an acceptable network is found.

Key-words: - Topological design, wireless network, Optimal algorithm, K-connected Network.

1 Introduction

The terms topological design, wireless network, K-connected network, gray code, degree of the node have the usual meaning. [1, 2 & 3]

1.1 Wireless Communication Network

It is also well known that the topological design of a wireless network is carried out using a minimum (K>2). We now present an optimum algorithm for the topological design of a K-connected network when the number of nodes is exactly equal to 2^K.

1.2 Wired Communication Network

The fastest available computers cannot optimize a 25 node network, let alone a 100 node network [3]. A potential network topology can be generated using the link deficit algorithm [4].This heuristic begins by numbering the nodes at random. In general, different starting networks result when the numbering of the nodes is changed [3]. The cost of a link is assumed to be proportional to its length. We now present an algorithm to number the nodes of a computer communication network when the entire nodes (assumed even in number) lie on a straight line, are equispaced and the connectivity that is sought is even.

1.3 Technical Issues

Many technical challenges must be addressed to enable the wireless applications of the future. These challenges extend across all aspects of the system design. As wireless terminals add more features these small devices must incorporate multiple modes of operation in order to support the different applications and media. Computers process voice, image, text and video data, but breakthroughs in circuit design are required to implement the same multimode operation in a cheap, lightweight, handheld device. Consumers don't want large batteries that frequently need recharging, so transmission and signal processing at the portable terminal must consume minimal power. The signal processing required to support multimedia applications and networking functions can be power intensive. Thus, wireless infrastructure-based networks, such as wireless LANs and cellular systems, place as much of the processing burden as possible on fixed sites with large power resources. The associated bottlenecks and single points of failure are clearly undesirable for the overall system. Ad Hoc wireless networks without infrastructure are highly appealing for many applications because of their flexibility and robustness. For these networks all processing and control must be performed by the network nodes in a distributed fashion, making energy efficiency challenging to achieve. Energy is a particularly critical resource in networks where nodes cannot recharge their batteries – for example, in sensing applications. Network design to meet application requirements under such hard energy constraints remains a big technological hurdle. The finite bandwidth and random variations of wireless channels also require robust applications that degrade gracefully as network performance degrades.

Design of wireless networks differ fundamentally from wired network design owing to the nature of the wireless channel. This channel is an unpredictable and difficult communications medium. First of all, the radio spectrum is a scarce resource that must be allocated too many different applications and systems. For this reason, spectrum is controlled by regulatory bodies both regionally and globally. A regional or global system operating in a given frequency band must obey the restrictions for that band set forth by the corresponding regulatory body. Spectrum can also be very expensive: in many countries spectral licenses are often auctioned to the biggest bidder. In the United States, companies spent over $ 9 billion for second-generation cellular licenses, and the auctions in Europe for third-generation cellular spectrum garnered around $ 100 billion (American). The spectrum obtained through these auctions must be used extremely efficiently to receive a reasonable return on the investment, and it must also be reused over and over in the same geographical area, thus requiring cellular system designs with high capacity and good performance. At frequencies around several gigahertz, wireless radio components with reasonable size, power consumption, and cost are available. However, the spectrum in the frequency range is extremely crowded. Thus technological breakthroughs to enable higher-frequency systems with the same cost and performance would greatly reduce the spectrum shortage. However, path loss at these higher frequencies is larger with omni directional antennas, thereby limiting range.

As a signal propagates through a wireless channel, it experiences random fluctuations in time if the transmitter, receiver, or surrounding objects are moving because of changing reflections and attenuation. Hence the characteristics of the channel appear to change randomly with time, which makes it difficult to design reliable systems with guaranteed performance. Security is also more difficult to implement in wireless systems, since the airwaves are susceptible to snooping by anyone with an RF antenna. The analog cellular systems have no security, and one can easily listen in on conversations by scanning the analog cellular frequency band. All digital cellular systems implement some level of encryption. However, with enough knowledge, time, and determination, most of these encryption methods can be cracked; indeed, several have been compromised. To support applications like electronic commerce and credit-card transactions, the wireless network must be secure against such listeners.

Wireless networking is also a significant challenge. The network must be able to locate a given user wherever it is among billions of globally distributed mobile terminals. It must then route a call to that user as it moves at speeds of up to 100 km/hr. The finite resources of the network must be allocated in a fair and efficient manner relative to changing user demands and locations. Moreover, there currently exists a tremendous infrastructure of wired networks: the telephone system, the internet, and fiber optic cables –

which could be used to connect wireless systems together into a global network. However, wireless systems with mobile users will never be able to compete with wired systems in terms of data rates and reliability. Interfacing between wireless and wired networks with vastly different performance capabilities is a difficult problem. Perhaps the most significant technical challenge in wireless network design is an overhaul of the design process itself. Wired networks are mostly designed according to a layered approach, whereby protocols associated with different layers of the system operation are designed in isolation, with baseline mechanisms to interface between layers. The layers in a wireless system include: the link or physical layer, which handles shared access to the communications medium; the network and transport layers, which route data across the network and ensure end-to-end data rates and data delivery; and the application layer, which dictates the end-to end rates and delay constraints associated with the application. While a layering methodology reduces complexity and facilitates modularity and standardization, it also leads to inefficiency and performance of wired networks makes these inefficiencies relatively benign for many wired network applications such as voice and video. The situation is very different in a wireless network. Wireless links can exhibit very poor performance, and this performance, along with user wireless links can exhibit very poor performance, and this performance, along with user connectivity and network topology, changes over time. In fact, the very notion of a wireless link is somewhat fuzzy owing to the nature of radio propagation and broadcasting. The dynamic nature and poor performance of the underlying wireless communication channel indicates that high-performance networks must be optimized for this channel and must be robust and adaptive to its variations, as well as to network dynamics. Thus, these networks required integrated and adaptive protocols at all layers, from the link layer to the application layer. This cross-layer protocol design requires interdisciplinary expertise in communications, signal processing, and network theory and design

2 Optimal Algorithm

The geographical positioning of 2^K nodes is placed at random. Our aim is to design a K-connected network. The nodes are labeled in an arbitrary fashion. The decimal number of each node is converted into a K bit Gray code. Thus each node has a Gray code associated with it. There exist a link between any two nodes whose Gray codes differ only in one place are connected. Thus every node gets connected to K nodes and has a degree of K.

2.1 Illustrative Example

The geographical positions of an 8 nodes are shown in Fig.1. It is desired to set up a 3-connected network. We observe that K=3

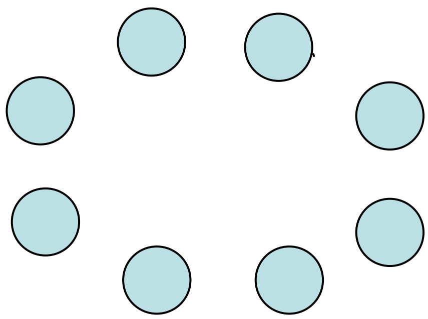

Fig.1, Geographical Positions of 8 nodes

Solution:

The nodes are labeled 0 through 7 in a systematic manner using the optimal algorithm and the decimal number of each node is as shown in Fig.2

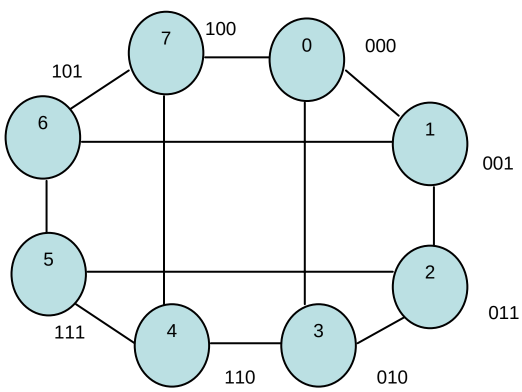

Fig.2. 3-Connected Network

The gray code is equivalent to decimal i where (0 ≤ i ≤ 7) is written by the side of node i as shown in Fig.2, Now any two nodes whose gray codes differ only in one place are directly connected network is shown in Fig.2.

3 Algorithm for Numbering the Nodes

The N nodes (N even) which lie on a straight line and are equispaced are shown in Fig.3

Fig.3

Starting from left, the nodes are successively numbered 1, 3, 5... (N- 1).The remaining nodes on the right are successively numbered N, (N-2), (N-4)… 2.

3.1 Illustrative Examples

Six nodes lie on a straight line and are equispaced. We desire to set up a 4- connected network. Using our algorithm, the nodes are labeled as shown in Fig.4

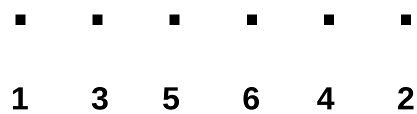

Fig.4

Application of the link deficit algorithm gives the starting network as shown in Fig.5.

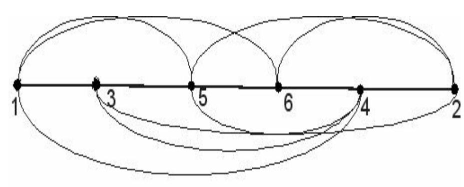

Fig. 5

It is easy to see that any other labeling of the nodes gives rise to a starting network with higher cost.

3.2 Significance of the Above Mentioned Numbering Scheme

In an Optical communication network, the numbering of nodes corresponds to placement of wavelength converters [5]. In an optical network, traffic congestion can be reduced by suitable placement of wavelength converters. In addition, flooding and loss of information packets is avoided and delay is reduced.

4 Conclusion

An optimal algorithm has been presented for the topological design of a K-connected wireless network. Our algorithm can be used only where the number of nodes is exactly equal to 2^K.

Also we have presented a systematic method for numbering the nodes (assumed even) of a computer communication network when all the nodes lie on a straight line, are equispaced and the connectivity that is sought is even. After an exhaustive study and search, the authors have observed that this numbering scheme gives the cheapest starting network.

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