Half-Duplex Spread Spectrum Networks

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ABSTRACT:

This paper is a response to the presentation of the TAPR SS Modem at the 1997 Digital Communications Conference in Baltimore, MD. At this conference, topology's were proposed for use of the SS radios and modems in a network, which the author of this paper feels are rather limiting. This paper proposes to extend the topology's available allowing implementation of a network rather than a collection of communicating nodes. This paper also builds on a number of ideas brought up in the authors undergraduate thesis.

Introduction

Expansion of radio based networks in amateur radio is process that is tied deeply to the technology used on the network. Packet radio links using FM radios succeeded because of the ability to incrementaly expand the network. To add another link, all that was needed was the hardware at the far end to be installed. In most cases, the link could be using existing hardware sharing time with existing links.

Put another way, amateurs find it much easier to set up one new station that two. This is especially the case when the equipment required for each station is quite expensive. This paper attempts to put the idea that a Spread Spectrum (SS) network can be designed to operate in a way that allows easy ad-hoc expansion. This paper addresses many of the problems seen in the protocols proposed for the forthcoming TAPR SS Radio.

Assumptions.

There are several basic assumptions made in this paper about the operation of the TAPR SS Radios:

- The system transmits data in 'TIMESLOTS' which are on a particular frequency for a particular period of time. During a timeslot, the frequency of the station does not change. After each timeslot, the frequency in use changes.
- That radios transmit in equal length timeslots - regardless of the amount of information to be transmitted.

- That stations throughout the network can keep track of timeslots through some absolute method (Averaged timings from adjacent stations or locked to a GPS based clock are two options)
- That it is possible for a station to hear a station that is not the closest station. That is the classic CDMA near-far problem doe not apply here. (This assumes that both stations are not transmitting on the same frequency in the same timeslot)

In the 1997 DCC two possible modes of operation were proposed for the new TAPR SS radio modem. These modes were a point to point link and a star network as shown in figure 1.

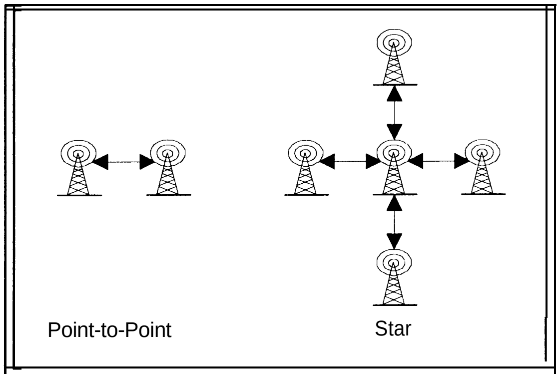

Figure 1

However in a spread spectrum situation this is not a good use of resources. This if especially so in the case of the star configuration. The utilisation can be defined as the time spent by all stations transmitting or receiving divided by the total time. In the start configuration with four stations, the utilisation becomes 16/40 or only 40%. This means that on average 60% of each stations time is being wasted.[1]

A network of Point-to-Point links would be ideal allowing for 100% utilisation, but this would require excessive infrastructure of a network was to be developed. All the stations in Figure 1 would share a common hopping sequence.

Compare this with a slightly smaller idealised situation on the next page . It is assumed that synchronisation can be maintained at all times. In this case the utilisation is 100%[2]. This layout is somewhere between a series of point-to-point links and a totally ad-hoc network.

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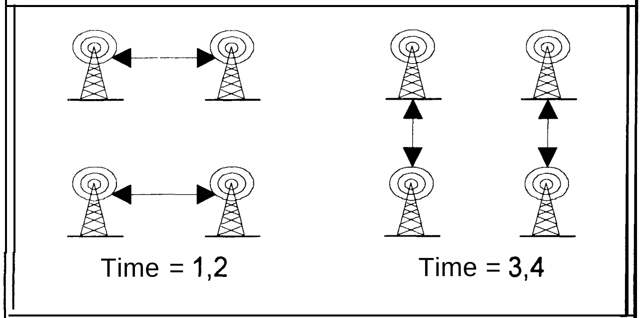
[1] A Star configuration with 5 total stations would need a timeslot for each station to send data to the central node, and another receive data from the central node. Eight transmission timeslots are required in total. This translates to eight transmitting timeslots and 8 receiving timeslots. During the 8 timeslots the 5 stations have a total capability of 40 timeslots to transmit or receive. (8+8)/(8*5) = 0.4 = 40%. A star network with 4 total stations would have a utilisation of 50%.

[2] The utilisation in this case is most easily computed by examining the amount of time that any radio is not transmitting or receiving. Since no time is wasted, the utilisation is 100%.



In this situation, pairs of stations would share hopping sequences. For timeslots 1 and 2, the upper pair of stations would share a hopping sequence. The lower stations would also share a different hopping sequence. In Timeslots 3 and 4, the stations on the left would share a hopping sequence, and the stations on the right would share a different hopping sequence.

Unfortunately such a topology does not scale well. In a real network we get a situation more like the one in figure 3. For a spread spectrum system to operate effectively and to be scalable, it must be able to cope with such a network.

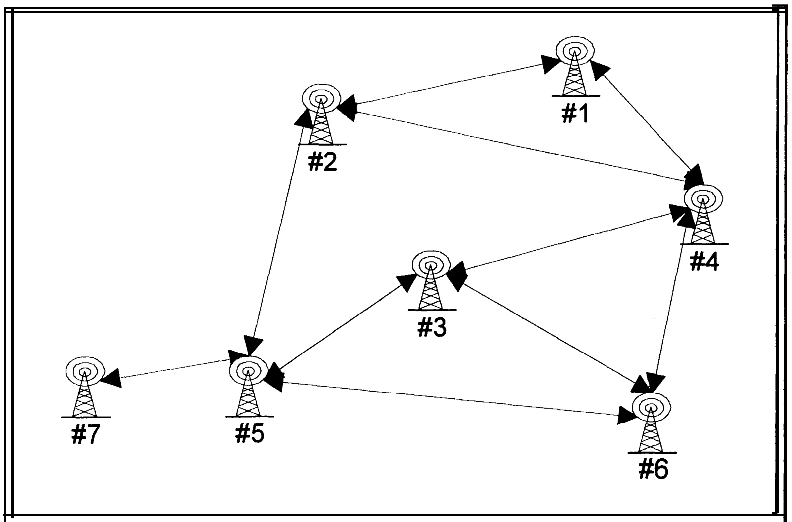


Figure 3

It can be seen that most of the time pairs of stations can communicate without any problems. However when stations 5 and 7 are communicating not all of the remaining 5 stations may communicate. This problem can only be minimised, but never eliminated.

In effect keeping the Assigned Timeslots number of unavailable stations as low as possible is one constraint for minimum energy routing.

If we are to realistically implement system as disorganised as the one in figure 3, we should look at a number of ideas.

Hopping Sequence
Each station in the network will share the same hopping sequence. Each station would be assigned a unique offset from the start of this hopping sequence, so that simultaneous transmission from all stations would be orthogonal.

Idle Mode
Each station should be listening for packets using their default hopping sequence to determine the frequency to monitor during each timeslot.

Transmitting Mode
During transmissions, the frequency used should be the frequency assigned to the receiving station for that particular timeslot.

By using just these rules to develop a network, we can see the efficiency of the network approach the 39% of Slotted Aloha.

But with any system, there is some information which is more important than others. There also tends to be a base loading and then peaks. It seems reasonable to design a network to cope with these aspects. I have therefore determined that timeslots should be coordinated between stations to reduce contention for some resources.

Routing and Time-slot Assignment

It has been shown that if power was controlled in a network, and if minimum energy routing were used, then a spread spectrum network is infinitely expandable. In the following section I have assumed that the layer above has determined the path that a packet will take. That leaves the stations just needing to work out how and when to send packets.

I propose that timeslots be assigned in a number of ways

FIXED

Periodically each station should have the opportunity to exchange information with it's neighbours, including data and planned timeslot assignments. By fixing some stations to timeslots the minimum information the network can transfer is increased.

ASSIGNED OR POLLED

During a stations fixed timeslot, it may request a number of additional timeslots over a period of time. On it's next transmission, a packet would be sent to the requesting station listing timeslots for use.

SLOTTED ALOHA

Each station will list some timeslots as being for Slotted Aloha use. These timeslots are transmitted to such as in Slotted Aloha. There is no way that other stations can determine if they are getting through, or blocking other stations dropping the maximum utilisation to 39%. However some traffic is so random that this will be the most efficient transmission mechanism.

Conclusions

In this paper I have not attempted to look at how timeslots are actually assigned and re-assigned, or how new stations are registered. I have not looked at routing protocols, but rather what happens when a decision on routing is made. I have attempted to show that some Spread Spectrum topology's are not as efficient to network scalability as others. I have also attempted to present a basis for further work on this subject.

I should point out once again that having a scalable network is essential for a spread spectrum network to operate. Without scalability, the effort is wasted. As was shown when FidoNet was introduced, a network of short links can work..