RF Link Power Control with Field Test Data

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Introduction:

Associated with the rapid concentration of forces there is the issue of EMC/EMI problems among various radios in a theater. The general issue is about how various narrow band radios can be brought to use in a battle field with automated RF power management. The study in this paper is restricted to point to point link power control. The concept of power management should also be applied to a number of radios in a network structure.

In order to achieve minimum possible co-channel interference a party at the link ends should radiate minimum power. It should be only enough to establish an adequate service (BER) for that particular distance and no more. In ideal situation path loss is proportional to the logarithm of the distance and transmission frequency. In real situation path loss is also affected by terrain features.

Radio links in battle field are not thermal noise limited. They are fading limited and interference limited from all sources. Channel fading has been attributed to multipath, scattering, and shading. Channel fading has been studied intensively mainly for short distances (1 to 10 km) in cellular telephone systems. Long range channel fading is still a serious problem for DOD.

In this study an UHF link with 19.2 kilo baud modems were setup between a base node and a mobile node. The goal is to study about possible power control algorithms that can track a minimal RF power for a particular BER. Output RF power is attenuated at increments in the algorithm. A range of RF power is allowed to change until a preset BER is achieved. In this paper the field tested data and the simulation results are presented.

Point to Point Power Control in a Link

The study is concentrated on two power control algorithms, fixed step algorithm and adaptive step algorithm. Point to point control algorithms will be used in a RF power management system which in general is actually a meshed type of RF network. The results obtained in this paper can be used as foundation in our further study.

Experimental Setup

We used two non-coherent FSK modems at 455.35 MHz. The modems in the Kentronix Data Engine TNC has a special mode that can generate error counts based on fixed bit patterns. BER can be calculated from the error count for power control algorithm.

QOS (BER) Prediction Model

In our field tests a quality of service (QOS) prediction model is available to provide an initial value for control. This prediction model should accept radio distance and terrain elevation data. Presently it accept only radio distance data. The prediction model allows a margin for channel fading. Based on the initial value from the model the power control algorithms will provide the required bit error rate (BER). The prediction model is also used to calculate the steps in the adaptive algorithm in the field tests.
The prediction model is based on the BER curve of a non coherent FSK system. Empirical test measurements on BER at a fixed distance allowed us to calibrate the model for the Kentronic modem and transceiver. For mobile nodes radio distance can be translated to shift of Eb/No in the model so that the initial power for tracking can be calculated. In the field tests only fixed mode pair are involved. On the other hand, in OPNET simulation mobile nodes with fixed step power control were demonstrated.

Fixed Step Power Control

The fixed step control algorithm introduce fixed step increments or decrements based on the comparison of the measured BER and the required BER. The fixed step is selected to be 0.5 dB which is the minimum possible settings in our programmable step attenuators. Figure 1 and 2 shows the BER and Attenuation versus time. As anticipated in any fixed step control algorithm there is the “overload” phenomenon. That is if the measured BER is too far away from the required BER, the fixed step algorithm will take longer time than desired to achieve the required BER.

Fixed Step Power Control with Hysteresis

There is also the problem of “granular noise” phenomenon if the measured BER is in slow varying situations. Here we introduced the hysteresis to minimize the granular noise effects which is clearly shown in our experimental data. Figure 3 and Figure 4 shows BER response and attenuation setting for the fixed step algorithm with hysteresis.

Jammer Setup

In our experiments a jammer emitter is introduced to cover the spectrum of the communication link. Two jammer power levels (-15 dBm and -21 dBm) are injected in sequence to watch for the response of the control algorithm. The evaluation are based on the transitional response of the BER and the smoothness of the BER due to presence of the jammer. Figure 5 and 6 shows the results in the presence of jammer.

Model Based Adaptive Step Power Control

The adaptive control algorithm is based on both the input of the QOS prediction model and a measured BER. Step size obtained from the model is used in the algorithm. The adaptive control algorithm performs much better than the fixed step control algorithm in the field tests.

The algorithm is implemented in a graphical programming environment called Labview. The algorithm allows input from the prediction model which mainly account for the radio distance. Because our field tests are conducted at a very short range (<100 meters), the fixed node prediction model provides values at very slow rate (10th second). Figure 7 and 8 shows attenuation control and the BER response for the adaptive step algorithm. As you can see that the response time of the adaptive control algorithm is much better than that of the fixed step algorithm.

Point to Point Power Control Simulation

OPNET is a software package that allows packet radio link simulation. To test mobile node power control in OPNET is much easier than field tests. One node is set up as the transmitter with a data rate of 9600 Baud operated at 300 MHz with a bandwidth of 25 KHz. There are 1024 bits within one packet, and the transmitter generates one packet in a second. The initial radiated power is 0.1 microwatts. The propagation model in OPNET follows free space loss without channel fading involved.

Fixed Nodes with Power Control
Two fixed nodes were arranged 3.5 Km apart. The control update interval is 3 seconds. The algorithm will maintain a BER of 0.75e-3 with a hysteresis of 0.25e-3. Simulation runs over 7 seconds. The power increment is 0.01 microwatts. In the simulation the fixed step control algorithm is adopted. Figure 9 shows the BER tracking with time. Figure 10 shows the received power, and figure 11 shows the average throughput. It is noticed that the tracking takes 3 minutes to reach target, and the average packet throughput increases with time monotonically.

**Mobile Nodes with Power Control**

For mobile nodes simulation transmitter node moves through a path approaching the receiver and departing from it later. Figure 12 shows the network configuration. The closest separation is 3.5 Km. The moving speed is 36 miles per hour which represents the scenario of a combatant ship. Again the fixed step algorithm is applied here. Target BER, hysteresis, power increment, and simulation run time are exactly the same as the fixed node simulation. Figure 13 shows the BER tracking. Figure 14 shows the received power, and figure 15 shows the average packet throughput over time. Notice that the tracking time to target BER is reduced to 1 minute because the radio distance between transmitter and receiver decreases with time. Therefore, the BER tracking improves with a faster speed than the fixed node situation. After 200 seconds the transmitter was not able to send packet. Consequently the average packet throughput deteriorated. This is attributed to the departing transmitter that reduced the received power faster than the algorithm can compensate. An adaptive algorithm in this case will do better than the fixed step algorithm.

**Conclusion**

In our work presented in this paper fixed node simulation yielded similar results as the field test data. Using fixed step algorithm the control slew rate problem showed up in the simulation results. The update rate can be increased to track the target BER faster. An adaptive algorithm is necessary to track BER in mobile node simulation. The adaptive step was calculated from the prediction model in our field tests. A simpler adaptive step can be based on doubling the step size if three consecutive steps are in the same direction. The results obtained in this effort is really a foundation for the network wide RF power management system.
References
Figure 10. Received Power versus time for Fixed Node Pair.

Figure 11. Ave. Throughput versus Time for Fixed Nodes Pair

Figure 12. Mobile Node Pair with Moving Path

Figure 13. BER versus Time for Mobile Node Pair

Figure 14. Ave. Received Power for Mobile Nodes

Figure 15. Ave. Packet Throughput for Mobile Node Pair