CHAPTER 9

CONCLUSION

Random access protocols derived for ultra high speed fiber optic networks have been introduced in this thesis. Twelve improved configurations using slotted scheme, persistent algorithm with and without collision detection feature have been proposed. The throughput-delay mathematical equations predicting the performances have been derived using the concepts of probability theory and poisson distribution model. The numerical results have been computed. System simulation experiments using random numbers have been carried out and the throughput-delay parameter values obtained from analytical models have been compared and verified. The computed numerical results have been plotted and studied in terms of sequence of curves that depict offered traffic versus throughput, offered traffic versus delay and throughput versus delay. The key results have been analysed and discussed. In all the configurations, the assumption and the parameter values as used with the existing scheme provides a fair frame work for comparison purpose. The hardware architecture to cross connect the users of the network considered here has been that of WDMA using passive star topology, since tandem taps in bus configuration introduce an exponential power attenuation which severely limits the maximum number of users. Effective optical implementation issues in terms of power budget and collision detection techniques have been assumed throughout the design for validating the results and discussions.

All configurations have shown it to be an efficient means for randomly accessing packet switched optical channels which have a small ratio of propagation delay to packet transmission time. From the
performance characteristics curves, we note that the behaviour of these schemes typical of contention systems, namely that the throughput increases as the offered channel traffic increases from zero, but reaches a maximum value for some optimum value of \( G_d \), and then constantly, decreases as \( G_d \) increases beyond that optimal value. Maximizing \( S_d \) with respect to the channel traffic rate \( G_d \) for each of the access modes leads to a channel capacity for that mode. The delay performance curves confirms the instability of contention-based protocols under heavy load. As the rate of new packets increases, so does the number of collision. It is found that both the number of collisions and the average delay grow exponentially with \( G_d \). The offered traffic versus delay and the throughput versus delay performance curves illustrates this point. The offered traffic versus delay curve shows that the delay increases exponentially with offered load. But the throughput versus delay curve reveals more meaningful performance. It shows that delay increases with throughput upto the maximum possible throughput. Beyond this point, although throughput declines because of increased number of collisions, the delay continues to rise.

These configurations provide a mechanism for trading five types of complexities for throughput-delay performance, namely, time synchronization, signal processing, collision feedback mechanism, Hardware complexity and pre-transmission delay. Time synchronized or slotted systems, adjust the transmission times of the various sources so that all packets arrive at a common point in the network at the same instant. Signal processing is used to avoid collisions by examining the channel before or during transmission. Incorporation of collision detection concept provide a better collision feedback mechanism. Reduced hardware complexity is achieved by the usage of single tunable optical devices. This aspect not only reduces the hardware complexity involved but also minimizes the cost. Finally the pre-transmission delay is avoided by means of continuous persistent algorithm. Slotted systems, persistent algorithm with collision detection feature collectively increases the throughput level to a considerable amount, and reduces the overall average delay. The protocol configurations
presented here have better throughput-delay performance than the existing protocols for all values of systems parameters. In typical applications, using the proposed configurations, an average throughput of upto 72 percent (in case of modified Aloha/CSMA), 36 and 38 percent (in case of modified CSMA/Aloha) have been achieved when compared to the existing protocol configuration's throughput of 63 percent and 18 percent respectively, with an overall average delay reduced down to several thousands of time units. These throughput-delay performance parameters are highly helpful in predicting the network behaviour under different loading conditions. This is very much useful in determining the behaviour of the system without going directly for the hardware implementations. A number of design examples that provide the network size, the supported user bit rate and associated parameters for the specific protocols also have been discussed. The proposed protocol configurations discussed herein can support larger size as well as smaller size fiber optic network that require a larger capacity.

There is a considerable scope for extending the results obtained from the throughput-delay performance analysis. The throughput-delay analysis is only one of a number of important measures of performance. This paradox arises because the concept of a multi-access network began with the satellite networks, where the cost of the medium (including the satellite) per unit of Bandwidth was very high. Later as local area networks were implemented with metallic cables of limited bandwidth, concern for the efficient use of that bandwidth persisted. However, as one begins to implement a real fiber optic network one must also be concerned with such things as efficient utilization of electronics (particularly high speed electronics), ease of interfacing terminals to the network, stability of the network system, delay uncertainties, reliability, re-arrangeability etc. All of these factors determine whether the network is useful and cost effective. The following is a listing of factors of importance in measuring the performance of fiber optic networks. For any given applications, different factors may be more important than other.
1. Network hardware and software cost: How much does it cost to buy and install the hardware and to buy software internally used by the network controllers (if any), as a function of number of accessing terminals and the features provided.

2. Efficient utilization of electronics: Is the complexity of electronics required to interface the network (including buffers in the accessing terminals) being traded appropriately to make efficient use of the available fiber bandwidth.

3. Delay uncertainty: Is the uncertainty in the transport delay due to contention for network resources or delay involved in processing the transmission errors.

4. Re-arrangeability: How difficult is it to add or remove accessing terminals. Are other terminals communication disturbed or interrupted in this process.

5. Number of Terminals: How many accessing terminals can the network support.

6. Reliability: What is the meantime between failures of a network elemented, what are the effects of various failures on the network.

7. Maintainability: How difficult is to diagnose, locate and repair failures.

8. Vulnerability: How can localized damage or improper operation of an accessing terminal affect the network.

9. Stability: How stable is the network system under different loading conditions.
10. Expandability: As new requirements appear, can they be accommodated by techniques such as dense wavelength length division multiplexing, optical bistable integrated circuits, Opto-Electronic Integrated Circuits (OEIC), coherent receivers, fine tunable quantum well lasers, optical switching etc.

The main purpose of this thesis is to introduce the concept of the random access protocol configurations and their improved throughput-delay performance analysis for ultra high speed fiber optic networks. Evaluation and extending the results to analyse the above discussed performance parameters would make the scope of the thesis too broad; therefore, this has been contemplated as future work.

In conclusion, this thesis introduces the concept of random access protocol and proposes a class of twelve random access protocol configurations and their improved throughput-delay performance analysis for ultra high speed fiber optic networks. The mathematical models, simulated numerical results and the discussions on the throughput-delay performance characteristic curves indicates the fact that, with the advancement in fiber optics technology especially in the area of tunable type of optical devices, photonic switching and coherent receivers, a very cost effective, reliable and simple fiber optic network can be realized with an excellent throughput-delay performance. With each user operating at gigabit logic and by having the lasers tunable range extending over to several thousands of distinct wavelengths, an aggregate system traffic data rate bandwidth of several terabit per second can be achieved using the proposed configurations. The protocol configurations discussed herein can support both the larger size as well as the smaller size Ultra High Speed Fiber Optic Networks.