A First Step Towards Autonomic Optical Burst Switched Networks

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I. Introduction

In recent years, Optical Burst Switching (OBS) is emerging as the dominant switching paradigm for transmitting IP traffic over WDM optical networks. This is mainly because OBS effectively combines the advantages of the two other switching paradigms for WDM networks, namely circuit and packet switching. For a detailed introduction to OBS networks, readers are referred to [1].

The large volume of data combined with the size and complexity of communication networks, make human management of such systems under network failures and other environment changes ill-affordable, and necessitate autonomy. In this paper, we propose for the first time, a self-optimizing and self-protecting autonomic OBS network system, which uses *Learning Automata* to *learn* and *adapt* to the state of the network. This self-awareness aids the system in making intelligent decisions. In this paper, we develop solutions for three fundamental problems: (i) Routing, (ii) Wavelength selection, and (iii) Protection.

Learning automata have been used in the past for solving the routing problem in communication networks, a detailed account of which is provided in [2]. There has been prior work addressing the problem of wavelength assignment in circuit-switched optical networks ([3] and references thereof). The same problem has received little attention in the case of OBS networks, although the impact on performance is much greater [4].

II. The Autonomic OBS Network System

We present a framework for our proposed autonomic OBS network system in Fig. 1. Every node in the system is equipped with this framework, consisting of learning automata, to continuously learn the network state from the feedback provided by the environment. The intelligence gained by these automatons is used to aid making control decisions that critically affect performance, and the decisions in turn affect the environment. We have implemented solutions for autonomic routing, wavelength selection, and protection, in OBS networks.

We assume that R candidate routes to every destination are precomputed and are available at all source nodes. Automatons placed at each node estimate the loss probabilities on all outgoing links. The loss probability estimate is initially set to some predefined value. When a burst is successfully transmitted over a link, a positive feedback is generated for the automaton, and when a burst is dropped on the link due to lack of an available channel to transmit the burst, a negative feedback is generated. Based on the updating scheme (discussed in section III), the automaton updates the loss probability estimate for the link.

The source of every connection periodically sends a probe packet along each of the R candidate routes to collect the loss probability estimates on all links along the route. Based on the loss probabilities of all the R routes, the best route is selected for burst transmission.

If the loss probability on the best route is not enough to meet the performance requirements of a connection, then the system can autonomously step into protection mode by choosing one of many available protection mechanisms. In this paper, we consider two protection mechanisms: Forward Error Correction (FEC) codes [5], and $1+1$ protection mechanism, wherein each data burst is transmitted independently on two link disjoint routes. Based on the loss probabilities of the various routes, the autonomic system decides from time to time, whether protection is required, and when necessary, chooses the protection mechanism which optimally satisfies the performance requirement.

We further develop for the first time, an intelligent autonomic wavelength assignment policy, which uses learning automata, to largely reduce losses due to contention and network failures. Automatons are placed at all source nodes, one for each possible destination, which continuously learn the state of the network.

In order to bring out the importance of wavelength

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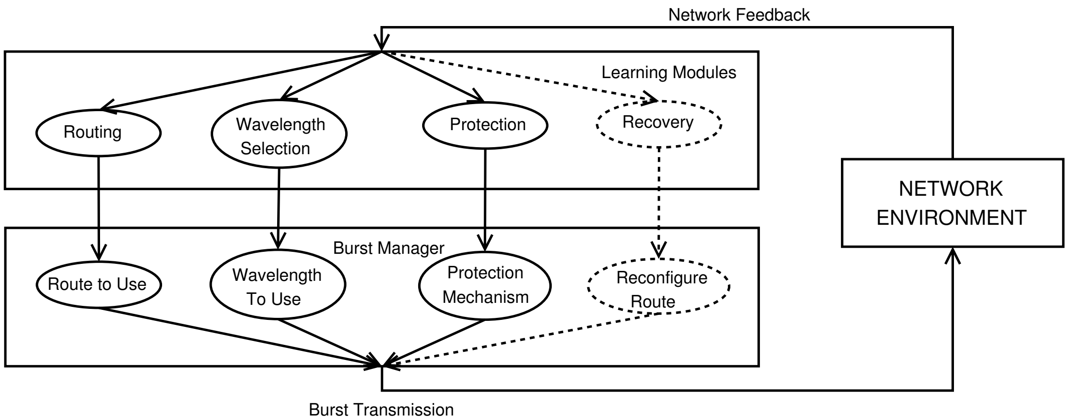

Fig. 1. Framework of a node in an Autonomic OBS Network System.

selection in OBS networks, we assume that routing is fixed and the shortest path between source and destination is used. We also assume that no node in the network is provided with wavelength conversion capability. The various states or actions of the automaton are the various wavelengths on any outgoing link. The automaton maintains probabilities, one for each of the states or wavelengths. Initially, all probabilities are equal. To transmit a burst from source S_i to destination S_j, the automaton at S_i for S_j stochastically chooses a wavelength based on the current probabilities. If the burst is successfully transmitted to the destination, a positive feedback is returned to the automaton. If the burst is dropped at some intermediate node due to contention, a negative feedback is returned to the automaton. The automaton, upon reception of the environment feedback, updates its probabilities based on the updating algorithm described in section III. This process continues for every burst that is transmitted.

III. The L_{R-P} Scheme

For both the routing as well as the wavelength selection problem, we decided to use the L_{R-P} scheme [2] to update the automaton action probabilities. When a positive response is obtained for an action, its probability is increased and the probabilities of all other actions are decreased. If a negative feedback is received for an action, the probability of that action is decreased and that of others is increased. For a multi-action system with S states, the updating algorithm can be written as follows, where $p_i(n)$ represents the probability of choosing action i at time instant n, and a and b are the reward and penalty parameters, respectively:

- When a positive feedback is obtained for action i,
  $p_i(n+1) = p_i(n) + a(1 - p_i(n))$
  $p_j(n+1) = (1-a)p_j(n), j \neq i$
- When a negative feedback is obtained for action i,
  $p_i(n+1) = (1-b)p_i(n)$
  $p_j(n+1) = \frac{b}{S-1} + (1-b)p_j(n)), j \neq i$

and similarly for all $i = 1, 2, \ldots, S$, where $0 < a < 1, 0 \leq b < 1$

IV. Conclusion

We have developed for the first time, a self-aware, self-optimizing and self-protecting system based on learning automata. Learning automata serve as an efficient tool to autonomously learn the state of the network and help in making intelligent decisions based on the knowledge gained. We have considered routing and wavelength selection problems in the context OBS networks and developed adaptive policies to solve them. Further, we have equipped the system with self-protecting capability against network failures and contention losses. Detailed description of our proposed mechanisms and experimental studies are presented in [6].

References

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