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Improved immunization strategy to reduce energy consumption on nodes traffic

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ABSTRACT

The increasing requirement of transmission network sizes would result in huge energy consumption with communication traffic. Green communication technologies are expected to help in reducing energy consumption impact to environment. Therefore, it is important to design energy-efficient strategy that can decrease energy consumption. This paper proposes to use the acquaintance and improved targeted immunization strategies from complex systems to resolve energy consumption issues and uses traffic as measure standard to obtain a stable threshold. The simulation results show that the improved control strategy is better and more effective to save as much energy as possible.

1. Introduction

Energy-efficient, which is also popularly referred to as green technologies, is keys to environmental protection. A lot of work has been done to develop green (i.e. energy efficient) solutions to engineering, including communication, network and so on. At the same time, the demand of communication technology caused increasing transmission requirement on optical networks. Furthermore, the prominent energy requirement leads to questions how to increase energy-efficient and save immense amounts of energy. For example, data centers account for 2% of the electricity consumed in the U.S., which grows at a rate of 12% [1]. Various trade-offs and balance are investigated between energy efficiency and other factors like bandwidth efficiency and delay [2,3]. It is important to solve the energy requirements since optical networks contain physical layers, sub-areas, and switching nodes that must be supported by lots of devices. Therefore , how to save energy to achieve "green" and energy efficient becomes significant.

In general, the energy consumption to the transmission network is unknown, but such networks cost substantial amounts of energy. In this area, there is a lack of detailed studies relating to expanded networks, and there are still many challenges concerning feasible adjustment modes [4]. Chiaraviglio et al. proposed a novel approach to switch-off network nodes and links that guarantees full connectivity and maximum link utilization [5]. Zhang et al. introduced the fundamentals and current progress on existing cognitive radio and self-organization techniques. They also surveyed optimal relay selection, optimal power allocation and large-scale MIMO [6–10], and they surveyed different aspects of bio-inspired mechanisms and examine various algorithms that have been applied to artificial SON systems. Ji *et al.* researched energy consumption problem from high-sampling-rate digital-to-analog converters (DACs) and WSS-based ROADM modules, which demonstrated as components and modules for all energy-efficient optical switching networks. And all optical transport network test-bed consisting of 10 Pbit/s level all optical switching nodes based on multi-level and multi-planar switching architecture is experimentally demonstrated for the first time, which can reduce power consumption by 43%, but they did not consider the controlling strategy based on software defined networking (SDN) for energy-efficient problem to all optical switching networks [11]. *Brendan Mumey et al. examined how to leverage the power down approach for green networking by studying a novel routing problem and presented an MILP formulation for the RPP to provide optimal solutions. Then they presented a shortest-path based algorithm and a tree based routing algorithm to solve it in polynomial time [12].*

Immunizing strategies are hot issue in network research. Liu *et al.* were concerned with designing a flexible immune algorithm suitable for most optical multicast networks; they modified a fitness function to reflect the level of individual excellence and to protect links [13]. Shams *et al.* proposed a new immunization strategy based on a stochastic hill-climbing algorithm to create a subset of nodes whose immunization efficiently reduced the network's vulnerability to worst-case epidemics [14]. Recently immunization strategies on complex

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system have improved the network information-processing capabilities and intelligence and the study of immunization strategies has become a new research subject in controlling research [15–19]. Zhao et al. proposed the immunization strategy based on complex systems that includes random and targeted immunizations to solve energy consumption issues and uses traffic to increase the energy saving effect [20].

This paper proposes the acquaintance and improved targeted immunization strategies to solve energy consumption problems in optical networks; these strategies are more feasible and convenient. In this paper, "green" strategies are proposed for a communication network and the paper is organized as follows. In Sec. II, the immunization technology is presented. In Sec. III, two immunization control strategies are used and derived. Those immunization controlling are then applied to achieving green communication. Finally, Section 4 concludes the paper.

2. Immunization technology

Learning biological intelligence, development, and then using the biological intelligence are eternal topic of evolutionary algorithms and intelligent computing. So the researchers try to study the concept of immunity in life science and introduce it to the field of engineering practice. Organically combining the relevant knowledge, theory and some intelligent algorithms, they establish a new evolutionary theory and algorithm to improve the overall performance of the algorithm. The immunization algorithm is based on the immune system of human and defined by simulating the recognition and combination between the antigen and antibody, and simulating the process of producing antibody. This kind of immunization algorithm can combine with the other algorithm just as the genetic algorithm and expert system. On the premise of reserving the original algorithm with good properties, we could restrain the degenerating phenomenon with some information or knowledge characteristics during the process of optimization.

To the transmission system, network devices can not act like monitors and other equipment which can switch into a power-saving mode to reduce energy consumption when idle. It leads to consuming significant energy. Energy-saving algorithms on communication network can be applied to SDN as follows:

(1) Set active state and immunized state to the network devices. The device rests when idle to save energy.
(2) Aggregate running routes to a few devices at the network level and reduce energy consumption when the network traffic load is low.
(3) Change the network protocol in the control layer for the optical links, which can flexibly adjust devices. Run devices when the load is high, and sleep the appropriate equipment when the load is low to increase energy efficiency.

Both acquaintance immunization and improved target immunization algorithms can reduce the power consumption, and this paper compares the different effects.

3. An immunization control strategy

We can use an immunization strategy to solve energy consumption and increase energy efficiency in optical networks, and we can immunize nodes with low traffic in the optical physical layer. This paper uses the acquaintance and improved target immunization strategies to solve this problem. *The nodes are divided into four gateway nodes and seven interior nodes because we want to study stability, precision and high response speed to controlling strategy gradually*. The gateway nodes use much more energy than the interior nodes; therefore, we use the gateway nodes for this strategy, as shown in Fig. 1. *Each link in the networks has 16 wavelengths and the same propagation delay. The traffic is uniformly distributed among all the node pairs, lightpath connection requests arrive following a Poisson process and with an exponentially distributed holding time. The data used is from the papers of Lifang Zhang [21]and Peng Ren [22].*

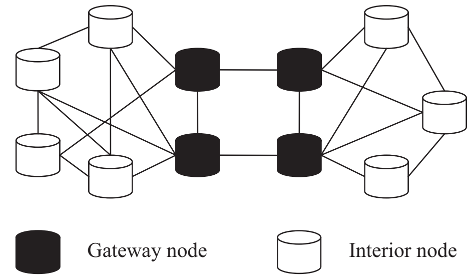

Fig. 1. Gateway and interior nodes in the routing domain.

3.1. The acquaintance immunization strategy

The acquaintance immunization strategy is to select one node with probability p from all nodes randomly and to select neighboring nodes to immunize from chosen nodes. f is the proportion of the total nodes that are immunized. This strategy is only able to obtain the nodes that are selected and directly connected neighboring nodes, and cleverly evades situations in which the immunization strategy requires global information. *Immune algorithm of this paper is based on the traffic of the nodes, manages the nodes to meet the sleep conditions and carries through energy saving. Because the core of the algorithm is traffic, we choose the node to sleep based on it. And we provide seven consecutive nodes for the simulation and the traffic probabilities are shown in Fig. 2*.

Using three sets of data, we select the nodes with traffic probabilities of less than 60% for acquaintance immunization. *We denote 60% of maximum traffic probabilities as p. In Fig. 2, the values of p in the three sets are 0.164, 0.145, and 0.134 respectively*.

In Fig. 2, the nodes selected from the first data set are [1–4]. The immunized neighboring nodes are [2–5]. Because the fifth node's traffic probability is greater than 60%, it is not immunized. Therefore, the number of immunized nodes is 3.

The nodes selected from the second data set are [1,4,7]. Because the traffic probability of all of the neighboring nodes is out of the 60% range, none of them can be immunized.

The nodes selected from the third data set are [1–4]. The immunized neighboring nodes are [2–5]. Because the fifth node's traffic probability does not meet the immunization condition, the

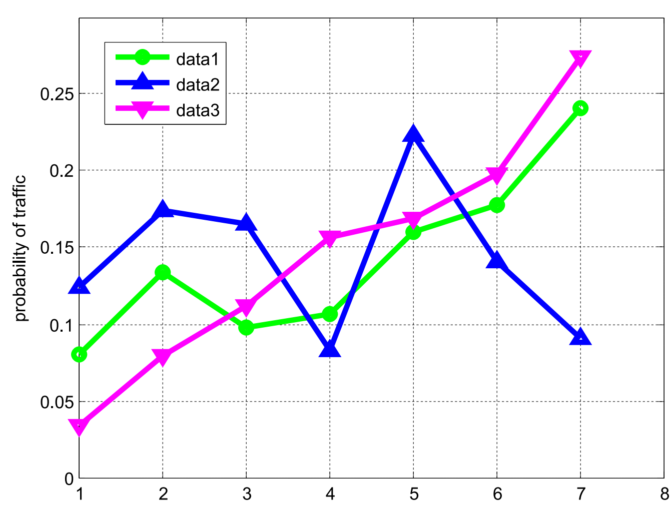

Fig. 2. The probability of traffic used for acquaintance immunization.