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Transmission Filters Utilizing Cavity Resonances in Bandgap-Engineered Monomaterials

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***Abstract*— A monomaterial-based resonator structure is proposed here, which can replace the multilayer-based narrowband transmission filter. This new concept of introducing the effect of multilayered structures of different materials into a single material is based on etching out repeatable structures of two different dimensions on the same material. As the etched-out repeatable structures are of different dimensions, it is possible to obtain periodic layers of two different-effective refractive indices. This type of monomaterial-based optical filters avoids the challenges generally faced while fabricating multilayer structures of different heterogeneous materials having different refractive indices. The dependence of the filter action on the number of bilayers of two different-effective refractive-index materials formed by etching and on the cavity region thicknesses is studied. Although the study is done mainly on lithium niobate on insulator, but it is seen that similar effects occur for materials of varying refractive indices.**

***Index Terms*— Band-pass filters, C band, optical resonator, periodic structure, WDM network.**

I. Introduction

OPTICAL filters are a vital component in wavelength-division multiplexing (WDM) transmission systems used in optical communications. A lot of work has already been done to design and develop various optical filters that can operate in the infrared (IR) and terahertz (THz) regions [1]–[5]. Narrowband filters have been fabricated by creating a cavity inside a one-dimensional photonic-bandgap (PBG) structure, which is actually a periodic layer of thin films of two dissimilar reflective materials. The choice of materials used depends upon the desired wavelength and can be dielectrics, metals, semiconductors, organic materials [5]–[8]. PBG structures follow the Fabry-Perot resonator principle, where the mirrors surrounding the cavity are formed by periodic spatial distributions of high- and low-index materials of a suitable refractive-index contrast. These structures utilize the effect of interferences of light to transmit light over a desirable wavelength range. The defect mode within the PBG causes the localization of photons with a corresponding resonant transmittance peak [9]. The chosen materials for these conventional multilayer thin-film interference filters must exhibit good transparency and physical robustness in this frequency region. Moreover, the materials used for developing thin-film interference optical filters usually have different thermal expansion coefficients and are fragile to thermal cycles. As a result, multilayer thin-film filters generally suffer from a large stress [4]. Maintaining a proper thickness with subwavelength dimensions is still a challenge. However, these problems can be avoided if the filter can be designed using a single material. In that case, the periodic variation of refractive index and the creation of defects are possible by complete etching of periodic repeatable structures of two different dimensions from a single material. The effective refractive index of each of the periodic layers will be different and so periodic variations of effective refractive index can be achieved. This concept is used here to design narrowband filters on a single material.

In this work, we have proposed a filter based on a single material (Lithium Niobate on Insulator, LNOI) with periodic structures of two different dimensions etched in it, which can work as a multilayer thin-film resonant filter. Monomaterial-based multilayer optical filters based on similar etched structures have previously been reported [4], [10]. While in [4] the fabrication involved costly equipment and yielded transmission of 65 $\sim$ 70%, the structure in [10] involved a simpler fabrication process but the device consisted of three parts and there was no definite relation between the etched structure dimensions among the different parts. In the monomaterial-based optical filter proposed here, the periodic etched structures are considered to be placed in a regular manner, which resembles the characteristics of a conventional PBG structure formed by two different materials. Moreover, these filters can give almost 100% transmission. Similar to multilayer thin-film filters, the quality (Q) value of the proposed monomaterial filter can be improved by increasing the number of bilayers. It is possible to achieve tunability of the proposed filter by changing the etched structure dimensions or by utilizing the electro-optic property of Lithium Niobate.

II. Numerical Analysis

The finite-difference time-domain (FDTD) method is used here to study the electromagnetic field propagation through the proposed PBG structure. Normal incidence of light is considered for the simulation. As normal incidence of light yields the same result for both transverse electric (TE) and transverse magnetic (TM) modes in dielectrics, the proposed structure is simulated using TE modes of light only. For a linear, isotropic, nondispersive material placed in a source-free region, wave-evolution equations for field values (in both

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LOCATION BASED ENERGY EFFICIENT SCHEME (LNE^2S) FOR MOBILE AD HOC NETWORKS

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***Abstract*—Based on the topology of underlying ad hoc network, an energy efficient scheme is proposed that takes care of comparative cost in individual links. Within single hop downlink neighbourhood of a node, multiple paths (single or multi-hop) may exist to various downlink neighbours. Depending upon energy consumption in each of them, LNE^2S selects the optimum one. Please note that, by the cost of communication from node n_i to n_j, LNE^2S understands the sum of costs of communication from n_i to n_j and n_j to n_i, because acknowledgements are indispensable for successful completion of a communication session. This is a very unique feature of LNE^2S. Moreover, an weight based sleeping strategy is also proposed where the best alternative of a node n_i bridges the gap between communicating uplink and downlink neighbours of n_i, where n_i goes to sleep.**

***Keywords*—Ad hoc network, downlink neighbor, energy efficiency, battery powered, energy-oriented link life, velocity oriented link life.**

1. INTRODUCTION

Ad hoc networks are self organized and consist of only some nodes that move freely with arbitrary velocity and direction. They do not require help of any pre-existing infrastructure or centralized administration. These networks are very helpful in emergency situations like war, natural disasters like flood, earthquake etc. where traditional wired networks fail to work. However, ad hoc networks suffer from challenges like unpredictable mobility, security, limited battery power and bandwidth [1]. Researchers are working hard to address these issues [2]. Since nodes in ad hoc networks are battery powered, energy efficiency is a matter of great concern for longevity and capability of the network. According to [3], at least 40% of initial or maximum battery power is required to remain in operable condition; 40% - 60% is satisfactory, 60% - 80% is good whereas the next higher range i.e. 80% - 100% is considered to be more than sufficient. Therefore it must be appreciated that battery power is a scarce resource and if in a multi-hop path, routers are not equipped with sufficient residual battery power, it may seriously affect percentage of live nodes in the network. Reason is that, as soon as a router n_j in an active communication path, runs out of battery power, the link from its predecessor n_i to n_j breaks. In order to repair the broken link n_i soon broadcasts route-request (RREQ) messages in the network. Routers that forward those messages will consume additional energy. If a large number of links in the network, break, then a lot of energy of various nodes will be simply wasted in forwarding RREQ packets. Some nodes may die and network may get partitioned too. All these would not have happened, if routers in active communication paths were equipped with sufficient energy. Therefore, preserving energy is very crucial for ad hoc networks.

In recent years, many techniques have been proposed to conserve energy in ad hoc networks. Some of them are, adjusting transmission power depending upon the distance between sender and receiver in a link, allowing nodes to go to sleep provided a suitable alternative is there. Our present contribution LNE^2S concentrates on finding optimum path to one hop downlink neighbors of a node n_i. Transmission power is also adjusted depending upon location of each individual downlink neighbor. Acknowledgements have an important role to play too. Reducing cost of communication from n_i to n_k requires reduction in cost of transmitting acknowledgements from n_k to n_i, too. Routers on the verge of exhaustion are allowed to go to sleep provided suitable replacements are available. This allows preserving energy without compromising with network throughput.

Rest of the paper is organized as follows. In section 2, some state of the art energy preservation techniques are discussed. Proposed technique is described in section 3. Section 4 illustrates LNE^2S with some examples. Sleeping strategy is described in section 5. Simulation results appear in section 6 while section 7 concludes the paper.

2. RELATED WORK

Energy conservation techniques in ad hoc networks apply mainly the following two approaches -
i) Adjusting transmission power
ii) Putting as many nodes as possible in sleep state

FPR :Fuzzy Controlled Probabilistic Rebroadcast in Mobile Ad Hoc Network

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***Abstract*— Broadcasting in mobile ad hoc networks is performed using various techniques like blind flooding, counter based broadcast, probabilistic broadcast etc. Among these flooding is the most primitive, where every node forwards the broadcast message whenever it gets the message for the first fine. However, duplicate copies of the same broadcast message are always eliminated. In spite of simplicity of the mechanism, it results in highly redundant retransmission, contention and collision in the network. This is popularly termed as broadcast storm problem. Probabilistic broadcast method reduces the broadcast probability from 1 to some fraction close to 0.5. Certain probabilistic scheme use fixed probability while some others take into account network size, total number of nodes etc. The proposed article fuzzy controlled probabilistic broadcast or FPR computes rebroadcast probability of a node based on various factors line distance of downlink neighbours of current node from broadcast source, left, right, top, bottom coordinators of nodes already covered, hop count etc. Simulation results reveal that the proposed protocol improves network throughput, saves a lot of rebroadcast while reducing end-to-end delay.**

Keywords—Ad hoc networks, broadcast region, flooding, hop count, rebroadcast probability, delay.

I. INTRODUCTION

A mobile ad hoc network consists of certain nodes that communicates via wireless links without any network infrastructure or centalised administration the nodes are free to move in arbitary direction and arrage themselves in time – varying network topologies. These are particularly used in emergency scenarios like war, natural disaster etc. [1, 5, 12, 19-21]. Communication in ad hoc network either single-hop or multi-hop. In a single hop conmmunication, destination stays within radio-range of source. On the other hand in multi-hop network, one or more routers have to bridge the gap between source and destination nodes.

In MANETs, broadcasting plays a crucial role as a means of diffusing a message from source node to all other nodes in the network. It is fundamental operation which is extensively used in route discovery, address resolution and many other network services in various routing protocols [14, 15, 17, 18, 19, 20]. These protocols typically rely on the simplistic form of broadcasting called flooding, in which node retransmit every unique received packet axactly ones.Although flooding achieves high success rates in reaching all node in the network, it produces excessive redundant rebroadcast messages. In a dense network, this often causes high contention and collision , leading to loss of precious bandwidth and battery power, a phenomenon called broadcast storm problem [3, 4, 6, 7-11].

To mitigate this problem, several broadcast schemes have been proposed. They are commonly divided into deterministic and probability or counter-based scheme. In deterministic scheme, nodes typically exchange 1 hop and 2 hop neighbour information to construct a vertual backbone covering all nodes in the network. This requires exchange of a huge number of messages because network topology varies with time [12, 14, 15, 16]; link make and break very often. Probabilistic scheme decide rebroadcast probability of each node based on different factors, like radio range, network density etc. If radio range of a node is high along with the network density,and it rebroadcasts a message then it is expected that a huge number of nodes will receive the broadcast message in the shot.In counter based scheme, messages are rebroadcast only when the number of copies received at a node less than the threshold value.

In this article we proposed a typically topology aware fuzzy control probabilistic scheme FPR where each node tries to find out how many uplink neighbours of its downlink neighbours are closer to the broadcast source. If most of them are closer to the source, then rebroadcast probability of the current node will be low. Moreover, whenever a node rebroadcasts, it computes the corresponding left, right, top and bottom limits. If most downlink neighbours of the current node link within that region (shall be termed as broadcast region onwards), the rebroadcast probability of the current node will be low. Another criterion that we consider is hop count. If hop count till the current node is close to maximum possible hop count in the network. Then rebroadcast probability of the current node will be low. Simulation results reveal that FPR achieves superior performance that state-of-the-art probabilistic broadcast scheme in literature.

Rest of the paper is organized as follows. Section 2 presents FPR in detail. Performance evaluation is given in section 3 while section 4 concludes the paper.