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An Novel Approach for Distributive Adaptive Opportunistic Routing in Wireless Ad Hoc Networks

Sheethal Raj T G [#1], Nithya E [*2]

[#] M.Tech Student, Department of Computer Science and Engg,
Dr. AIT,Bangalore-560 056, Affiliated to VTU, Belgaum, INDIA
[1] sheethalrajtg@gmail.com

[*] Assistant Professor, Department of Computer Science and Engg,
Dr. AIT, Bangalore-560 056, Affiliated to VTU, Belgaum, INDIA
[2] nithyae@gmail.com

***Abstract*—A distributed adaptive opportunistic routing scheme for multi hop wireless ad hoc networks is proposed. The proposed scheme utilizes a reinforcement learning framework to opportunistically route the packets even in the absence of reliable knowledge about channel statistics and network model. This scheme is shown to be optimal with respect to an expected average per-packet reward criterion. The proposed routing scheme jointly addresses the issues of learning and routing in an opportunistic context, where the network structure is characterized by the transmission success probabilities. In particular, this learning framework leads to a stochastic routing scheme that optimally "explores" and "exploits" the opportunities in the network. The problem of opportunistically routing packets in a wireless multi-hop network when zero or erroneous knowledge of transmission success probabilities and network topology is available. Using a reinforcement learning framework, we propose a distributed adaptive opportunistic routing algorithm (d-AdaptOR) that minimizes the expected average per-packet cost for routing a packet from a source node to a destination. This is achieved by both sufficiently exploring the network using data packets and exploiting the best routing opportunities.**

Keywords: Opportunistic routing, wireless ad hoc networks, stochastic routing, learning framework, network model

I. INTRODUCTION

Opportunistic routing for multi-hop wireless ad hoc networks has seen recent research interest to overcome deficiencies of conventional routing as applied in wireless setting .Motivated by classical routing solution in the internet, conventional routing in ad hoc network attempts to find a fixed path along which the packets are forwarded .such fixed path schemes fail to take advantage of broadcast nature and opportunities provided by the wireless medium and results in unnecessary packets retransmission. The opportunistic routing decisions, in contrast are made in an online manner by choosing the next relay based on the actual transmission outcomes as well as a rank ordering of neighbouring nodes.

In this paper, we first investigate the problem of opportunistically routing packets in a wireless multi-hop network when zero or erroneous knowledge of transmission success probabilities and network topology is available. Using a reinforcement learning framework, we propose a distributed adaptive opportunistic routing algorithm (d-AdaptOR) that minimizes the expected average per-packet cost for routing a packet from a source node to a destination. This is achieved by both sufficiently exploring the network using data packets and exploiting the best routing opportunities. Our proposed reinforcement learning framework allows for a low-complexity, low-overhead, distributed asynchronous implementation. The significant characteristics of d-Adaptor are that it is oblivious to the initial knowledge about the network, it is distributed, and it is asynchronous.

The main contribution of this paper is to provide an opportunistic routing algorithm that: 1) assumes no knowledge about the channel statistics and network, but 2) uses a reinforcement learning framework in order to enable the nodes to adapt their routing strategies, and 3) optimally exploits the statistical opportunities and receiver diversity.

II. RELATED WORK

An easy way to comply with the conference paper formatting requirements is to use this document as a template and simply type your text into it. The authors in focus on heuristic routing algorithms that adaptively identify the least congested path in a wired network. If the network congestion, hence delay were to be replaced by time-invariant quantities,

1. The heuristics in would become a special case of d-AdaptOR in a network with deterministic channels and with no receiver diversity. Ant routing uses ant-like probes to find paths of optimal costs such as expected hop count, expected delay, and packet loss probability.

2. This dependence on ant-like probing represents a stark difference with our approach where d-AdaptOR relies solely on data packet for exploration.

The main disadvantages of the existing systems are:

- Ant routing uses ant-like probes to find paths of optimal costs such as expected hop count.
- Expected delay.
- Packet loss.

Stochastic Routing in Ad-Hoc Networks: In this paper, authors have investigated a network routing problem where a probabilistic local broadcast transmission model is used to determine routing. We discuss this model's key features, and note that the local broadcast transmission model can be viewed as soft handoff for an ad-hoc network. We present results showing that an index policy is optimal for the routing problem. We extend the network model to allow for control of transmission type, and prove that the index nature of the optimal routing policy remains unchanged. We present three distributed algorithms which compute an optimal routing policy, discuss their convergence properties, and demonstrate their performance through simulation.

Selection diversity forwarding in a multi-hop packet radio network with fading channel and capture: In this paper, forwarding methods for wireless mobile multi hop networking in Rayleigh fading and non-fading channels are examined. An adaptive forwarding scheme denoted Selection Diversity Forwarding (SDF) is introduced and compared with two classical forwarding methods. It is shown that SDF presents significant performance improvements. In particular and in contrast to the reference methods NFP and MFR, the performance of SDF is enhanced under fading channel conditions. It is found that local path adaptation has potential to perform better than routing approaches along a single path.

Geographic random forwarding (GeRaF) for ad hoc and sensor networks : Multi-hop performance ExOR: Opportunistic multi-hop routing for wireless networks, A Simplified analysis is given first , some relevant tradeoffs are highlighted ,and parameter optimization is pursued ,further , a semi - Markov model is developed which provides a more accurate performance evaluation . Simulation results supporting the validity of analytical approach are also provided.

Exploiting path diversity in the link layer in wireless ad hoc networks: An integrated routing and MAC protocol that increases the throughput of large unicast transfers in multi-hop wireless networks. ExOR chooses each hop of a packet's route after the transmission for that hop, so that the choice can react which intermediate nodes actually received the transmission. This deferred choice gives each transmission multiple opportunities to make progress. As a result ExOR can use long radio links with high loss rates , which would be avoided by traditional routing. ExOR in-creases a connection's throughput while using no more net-work capacity than traditional routing.

Stochastic routing in ad hoc networks: We investigate a network routing problem where a probabilistic local broadcast transmission model is used to determine routing. We discuss this model's key features, and note that the local broadcast transmission model can be viewed as soft handoff for an ad-hoc network. We present results showing that an index policy is optimal for the routing problem. We extend the network model to allow for control of transmission type, and prove that the index nature of the optimal routing policy remains unchanged. We present three distributed algorithms which compute an optimal routing policy, discuss their convergence properties, and demonstrate their performance through simulation.

Discrete Stochastic Dynamic Programming: The general discrete-time linear quadratic stochastic control problem. This problem is solved in two steps. Dynamic programming is used to obtain a solution to the stochastic control problem in which perfect measurements of the state are available. Then the stochastic control problem in which only noisy measurements of a linear operator on the state are available is converted into a new stochastic control problem in which perfect measurements of the state are available. This conversion is based upon Kalman filter theory and is valid whenever the disturbances and measurement noises are Gaussian.

III. Proposed Scheme for opportunistic routing

The proposed scheme utilizes a reinforcement learning framework to opportunistically route the packets even in the absence of reliable knowledge about channel statistics and network model. we first investigate the problem of opportunistically routing packets in a wireless multi-hop network when zero or erroneous knowledge of transmission success probabilities and network topology is available. Using a reinforcement learning framework, we propose a distributed adaptive opportunistic routing algorithm (d-AdaptOR) that minimizes the expected average per-packet cost for routing a packet from a source node to a destination. This is achieved by both sufficiently exploring the network using data packets and exploiting the best routing opportunities. Our proposed reinforcement learning framework allows for a low-complexity, low-overhead, distributed asynchronous implementation. The significant characteristics of d-AdaptOR are that it is oblivious to the initial knowledge about the network, it is distributed, and it is asynchronous.

The advantages of the proposed scheme are:

The proposed reinforcement learning framework allows for a low-complexity, low-overhead, distributed asynchronous implementation. The significant characteristics of d-AdaptOR are that it is oblivious to the initial knowledge about the network, it is distributed, and it is asynchronous.

The framework allows for a low-complexity, low-overhead, distributed asynchronous implementation. The significant characteristics of d-AdaptOR are that it is oblivious to the initial knowledge about the network, it is distributed, and it is asynchronous. The main contribution of this paper is to provide an opportunistic routing algorithm that:

1) Assumes no knowledge about the channel statistics and network, but

2) Uses a reinforcement learning framework in order to enable the nodes to adapt their routing strategies

3) Optimally exploits the statistical opportunities and receiver diversity. In doing so, we build on the Markov decision formulation and an important theorem in Q-learning proved in.

There are many learning-based routing solutions (both heuristic or analytically driven) for conventional routing in wireless or wired networks None of these solutions exploits the receiver diversity gain in the context of opportunistic routing. However, for the sake of completeness, we provide a brief overview of the existing approaches. The authors in focus on heuristic routing algorithms that adaptively identify the least congested path in a wired network. If the network congestion, hence delay, were to be replaced by time-invariant quantities, the heuristics in would become a special case of d-AdaptOR in a network with deterministic channels and with no receiver diversity. In this light, it provides analytic guarantees for the heuristics obtained In analytic results for ant routing are obtained in wired networks without opportunism .Ant routing uses ant-like probes to find paths of optimal costs such as expected hop count, expected delay, and packet loss probability. This dependence on ant-like probing represents a stark difference with our approach where d-AdaptOR relies solely on data packet for exploration. The rest of the paper is organized as follows. In , we discuss the system model and formulate the problem. formally introduces our proposed adaptive routing algorithm, d-AdaptOR. We then state and prove the optimality theorem ford-AdaptOR

IV. Distributed Algorithm for opportunistic routing

Let us assume that there are *Si* set of neighbours and a node *i* itself. *Qi* denote the set of potential receiving nodes outcome due to a transmission from node *i*. The routing decision at any given time is done based on the reception outcomes and involves retransmission, choosing the next relay or termination. The decisions are made in a distributed manner following the three-way handshake between node *i* and its neighbours.

At time *k*, node *i* transmits a packet. The set of nodes *Si* who have successfully received the packet from node *i*, transmit acknowledgment (ACK) packet to node *i*. The acknowledgment packet of node includes a control message known as estimated best score (EBS). In third stage, the node *i* announces node *j* as the next transmitter or announces the termination decision in a forwarding packet.

There are four components of the algorithm: Initialization, Transmission Stage, Reception and acknowledgment stage, Relay Stage and Adaptive Computation Stage.

A. *Initialization*:

Initialize all the nodes.

B. *Transmission Stage*:

This stage occurs at time *n* in which node *i* transmit if it has packet for transmission

C. *Reception and acknowledgment Stage:*

Si denotes the random set of nodes that have received the packet transmitted by node *i*. In this stage, successful reception of the packet transmitted by node *i* is acknowledged to it by all the nodes in the *Si*. The delay for the acknowledgment stage is small enough (not more than the duration of the time slot) such that node *i* infers *Si* by time *n*. For all the nodes the ACK packet of node j to node i includes the EBS message. Upon reception and acknowledgment the counting random variable *Nn* is incremented.

D. *Relay Stage*

In this stage node i select a routing action according to the randomized rule parameterized by forwarding probability. The node i transmit control packet that contains information about routing decision at some time strictly between two intervals. Upon selection of routing action, the counting variable is updated.

E. *Adaptive Computation Stage:*

At time (n+1), after being done with transmission and relaying, node i updates score vector. Node i updates its EBS message for future acknowledgments.

V. Functioning of ADAPT-OR

The following steps are carried out while working with the algorithm:

- Get the registration details of the node. Perform the node login step.
- Node is created. Select the file to be sent
- Select the Source and Destination and Path Construction is done
- The Down Time (DT), Life Time (LT) are maintained.
- If the node status less than successful probability of data transmission then select the Alternate Path.

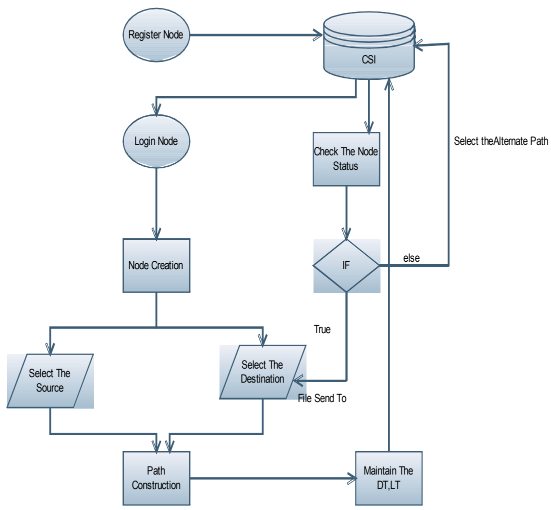

Fig. 1. Flow chart showing the different steps in AdaptOR

VI. Conclusion

We have implemented a distributed, adaptive and opportunistic routing algorithm – AdaptOR. This algorithm performance is found to be optimal with zero knowledge of network topology and channel statistics. The performance is measured in terms of the expected per packet reward. The algorithm is fully compatible and supports asynchronous 802.11 standard, which is implemented in JAVA swing for user interaction, core Java is used for algorithm implementation and backend to store node registration details MySQL server is used. The result shows that adaptOR consistently outperforms the existing adaptive routing algorithms in practical settings.

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