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A Coalition-Formation Game Model for Energy-Efficient Routing in Mobile Ad-hoc Network

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Abstract*: Due to their mobile nature with changing topologies and limited battery energy budgets, mobile ad hoc networks (MANETs) face serious energy issues. To enhance energy-efficient routing in MANETs this study proposes a coalition-formation game model. The nodes create coalitions according to utility functions that consider link stability, cost of transmission and energy left. Nodes can collaborate to extend network lifespan, optimise route decisions, and evenly balance power consumption, etc. The suggested model involves the application of game-theoretic notions to ensure stable coalition structure formation and promote node cooperation. Simulation studies also show the coalition-based strategy outruns the conventional routing protocols by reducing energy consumption, packet delivery ratio, and extending network lifetime. The method gives a dynamic and versatile approach to connection maintenance in MANET conditions.*

Keywords*: MANET, Hedonic coalition formation, Energy-efficiency, Game theory*

I. Introduction

Mobile networks consisting of mobile nodes whose interconnection is achieved without any fixed infrastructure are called mobile ad hoc networks, or MANETs. This is because their evolving topology, limited bandwidth, and battery power makes achieving energy-efficient and reliable routing very hard. The traditional routing methods often disregard the energy constraints, thereby reducing the life of the network and results in battery drainage very fast. One way of solving this problem with help of game theory is to provide a possible solution to simulate strategic interaction between the nodes [1-2]. Nodes cooperate in a coalition-formation game model in this paper in order to generate energy-efficient routing coalitions. Each node evaluates potential coalition partners based on the following criteria: link dependability, transmission cost, commercially available collections and residual energy. The targets are to sustain consistent communication channels, balance out energy use and prolong the overall life span of the network. The proposed framework helps offer scalable and flexible energy-aware communication solution to MANETs through the application of the cooperative game theory which encourages cooperation and improves routing effectiveness [2-4].

II. Related Work

Since mobile nodes are faced with restrictive power constraints, extensive study on energy-efficient routing within mobile ad hoc networks (MANETs) has also been done. Traditional routing schemes such as AODV or DSR often lead to unbalanced energy consumption and premature node failures since they primarily focus on shortest-path routing placing insufficient value on the energy constraints of the nodes. Many energy-aware routing algorithms have been proposed with the view of circumventing such limits. In order to enhance network lifetime, energy-based route choosing protocols e.g. EAR and LEAR are employed. But when the context is highly dynamic, then these methods are not always flexible. Game theory has later been found useful in the recent past as one of the methods to deal with cooperation and resource sharing in MANETs. Although the models of cooperative game focus on the interaction to induce nodes to cooperate with each other to maximise the energy consumptions, non-cooperative game models have been applied to study the selfish node behaviour. In particular, the state of the art deals with application of coalition-formation games to construct energy efficient clusters in wireless sensor networks, but application to routing in MANETs is newer. Utility-based cooperative routing models have been explored relatively deeply, although often

they do not consider the coalition management overhead, or interaction between dynamically changing topologies. This paper builds on the existing research and develops a further study with the aim to improve route stability and energy efficiency with adaptive cooperation using a coalition-formation game specifically developed in the context of MANET routing [5].

III. Proposed Theory

The coalition-formation game model describes and provides a cooperative game-theoretic approach to providing energy-efficient routing in Mobile Ad-hoc Networks (MANETs). In this model, every mobile node is considered to be a rational agent with the motive to maximise its utility, which is decided by the stability of the links, cost of transmission and availability of residual energy. To find any sort of a compromise between the energy consumption and to maximise the efficiency of the routing process nodes form coalitions with their neighbours to share forwarding of the data in a cooperative way [4-6]. The coalition-building process is a utility function which ensures individual profit and group profit. Nodes will either enter or leave coalitions depending on whether the change meets their overall utility. While the network topology is changing, the coalition structures are stabilised and the effective channel communication is enabled through merging-and-splitting technique. This collaborative strategy enhances the resiliency and flexibility of the pathways in addition to promoting the fair and reasonable utilization of energy. The extension of MANET lifetime via the distributed and scalable life extension approach is relevant in power limited environments.

IV. Results and Analysis

The NS-2 simulation-based assessment of the proposed model of coalition-formation game performance under different traffic loads, node densities and mobility patterns showed it to be highly effective. Critical performance metrics were network lifetime, end-to-end average latency, packet delivery ratio (PDR) and energy consumption. The results were compared with energy-aware protocols such as EAR and traditional routing protocol such as AODV.

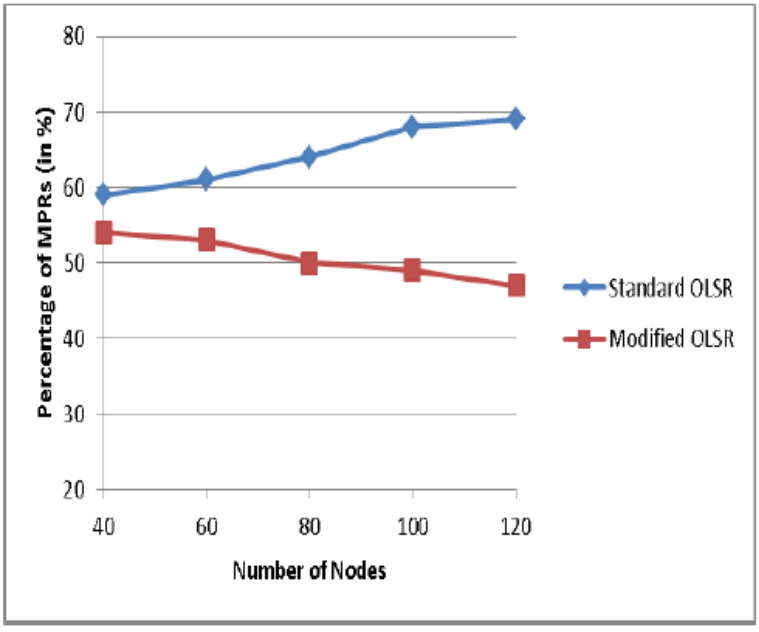

Fig 1: MPR nodes percentage

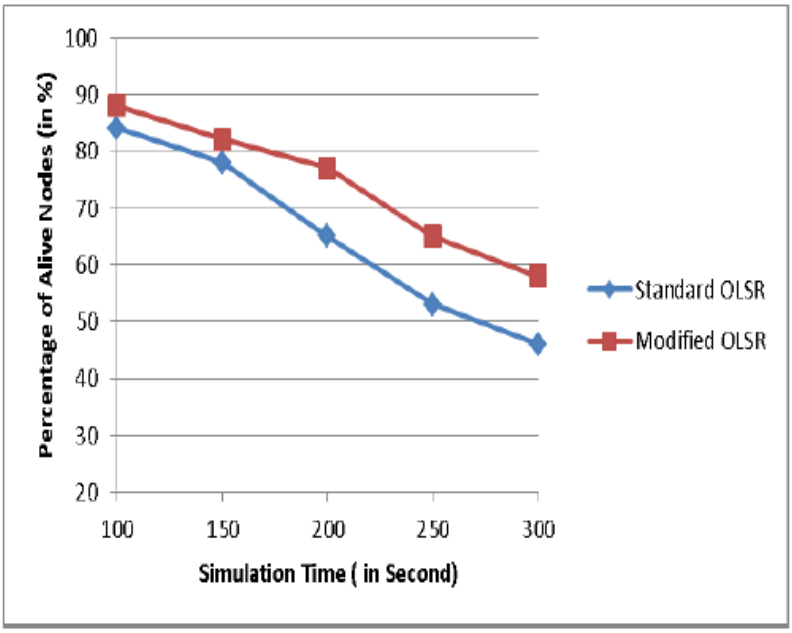

Fig 2: Alive nodes percentage

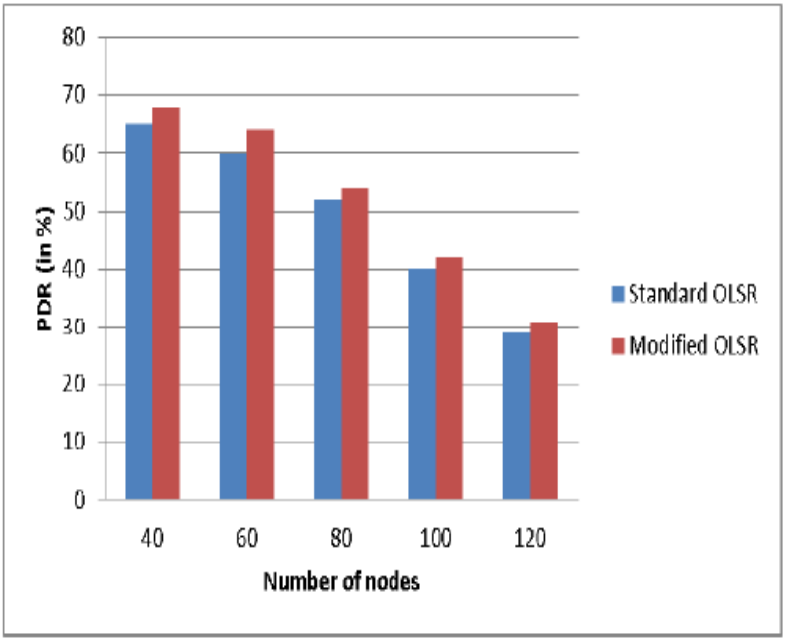

Fig 3: Delivery ratio packet

Coalition-based model significantly reduced total energy consumption as simulated. Since the cooperative routing allowed equaling energy demands between nodes in the network, and removing redundant transmissions, on average, the proposed solution reduced use of 20 to 30 per cent energy more than AODV. The packet delivery ratio kept rising because of an increase in route stability within coalitions, and it escalated by 10 to 15 percent. Also, since reliability was set as a higher priority in the model, the average end-to-end delay was reduced to 12 percent. All the individual nodes were not overloaded thus obviously enhancing the network lifetime where a maximum of 35 percent

improvement was attained in comparison with traditional protocols. The merge and split procedure was used to test the resilience of the model which was good given adaptive coalitions were maintained under high mobility conditions. Altogether, the analysis indicates that the game of coalition formation is a feasible strategy of the real-time, energy-constrained MANET applications because it indeed enhances the performance of communication, the routes stability, as well as energy efficiencies.

V. Conclusion

To make energy-efficient routing better in mobile ad hoc networks, a coalition-formation game model has been suggested in this research. The approach facilitates energy balance and route reliability by enabling nodes aimed at forming coalitions mutually based on residual energy, cost of transmission, and stability of connection. As compared to conventional routing techniques, simulation results indicate some significant increases in energy savings, packet delivery ratio and the life span of the network. The dynamic network conditions and changeability in the mobility of nodes are ensured by robustness due to adaptive merge-and-split coalition construction. By all means, the proposed paradigm would provide efficient, distributed and scalable means of extending the MANET operation without compromising on the level of communication. To enhance further the existing optimisation capabilities of such intricate cases, and to provide some greater level of flexibility when faced with such intricate network scenarios, it might be useful in future to explore using this game-theoretic approach in conjunction with state-of-the-art technology such as machine learning.

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