

DESIGN AND EVALUATION OF FAIRNESS-DRIVEN INCENTIVE MODELS FOR RELAY SELECTION IN COOPERATIVE COMMUNICATION

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ABSTRACT : *The advantages of cooperative wireless communication depends on selection of relay nodes. The nodes can be selected based on various criteria. This selection model should take care that nodes should not be overused. So fairness must be taken care when selecting relay for data transmission. For individual transmission, it may be less rewarding but it will improve the network throughput and energy efficiency. For long term cooperation tradeoff between fairness and incentive must be taken care. In this paper, we have proposed a relay selection method which takes care of energy efficiency, number of previous data transmissions handled by node and fairness. By combining these parameters we have ensured that network availability is maximum with maximum advantage to all the nodes who have participated in cooperation.*

KEY WORDS : *Cooperative Communication, Relay Selection, Incentive Model, Fairness*

1. Introduction

Cooperative Wireless Communication (CWC) is a communication paradigm in wireless networks where multiple nodes collaborate to transmit data, which enhances the overall performance of the network. Instead of only depending on direct transmission from source to destination, cooperative communication leverages intermediate nodes (relays) to forward data transmission. It improves network reliability, coverage, energy efficiency and spectral efficiency.

Relay selection is a critical component in cooperative wireless communication systems. It improves various aspects of network performance such as throughput, energy efficiency, reliability, and coverage. Wireless channels are prone to fading and interference. A relay can help in avoiding use of low performance direct link by providing an alternate path. Proper relay selection ensures that the best relay link is chosen, which helps in improving the signal-to-noise ratio (SNR) and reducing bit error rates. (Y. Zou et. al., 2013). Optimal relay selection can improve the data rate. There are certain areas in which energy efficiency is most important. (S. Abdulhadi et. al. 2010) Relay selection can be done based on energy efficiency parameters too. For real life streaming applications relay selection should be based on reducing latency and providing maximize QoS. Relay selection can be done on base of load balancing, which prevents excessive use of single relay and eventually that maps into high network availability. Fairness amongst nodes for relay selection will ensure that no relay will be excessively used and every node gets fair chance to participate in cooperation.

In cooperative wireless networks, relay nodes spend their resources (i.e. energy, bandwidth, etc.) to help others. To

maintain long-term cooperation, fairness and incentives are important. However, designing such mechanisms poses several challenges. Nodes have different channel condition, energy level and connectivity. Treating all nodes equal will be unjustifiable. Some nodes may be at favorable position, selecting them again and again will deplete their energy and reduce their interest in cooperation. Mobility will pose issues in selection of fair relay. Some nodes may behave in selfish manner. Ensuring fairness between selfish and cooperating node will be quite difficult.

Nodes will help in communication to get incentives. Allotment of incentive is difficult as the measurement of amount of help by node in communication is unmeasurable. Few nodes may submit false claim for incentives. Identifying such nodes is difficult. Maintaining and monitoring of cooperative activity for each node will increase the overhead. Nodes may look for immediate incentive after completion of their work as relay.

2. Relay selection Algorithm

Relay selection algorithms are important in cooperative wireless networks, where intermediate nodes (relays) assist in forwarding data from a source to a destination. These algorithms improve reliability, coverage, and spectral efficiency. Selection based on channel quality, energy efficiency or similar parameters will improve overall network performance.

Best relay selection can be done based on best end to end signal to noise ratio (S/N). Relays with channel quality above certain threshold can also be selected. Relays can be selected based on available residual energy. By selecting them network longevity is ensured. Relays can

compete amongst each other to get the data transmission job. Relay set inverse timer based on their condition and the relay whose timer goes down becomes one who gets the data transmission. Trust aware and social tie based relay selection are also introduced. (M. A. Jadoon and S. Kim, 2017)

Fairness in relay selection is an important design consideration in cooperative wireless communication systems. These systems depend on intermediate nodes (relays) to assist in data transmission between a source and a destination, improving reliability, coverage, and throughput. However, repeatedly selecting the same or "best" relay nodes can lead to unbalanced resource usage, faster energy depletion of selected relays, Network lifetime reduction and Lack of cooperation from nodes being overused. Fairness among users will provide equal opportunity to all nodes to transmit their data. Fairness in relay selection will improve network lifetime. (S. S. Kalamkar, 2016)

Relays are selected in a fixed rotating manner irrespective of instantaneous channel condition. Relays are selected based on certain utility function which may include fairness metrics such as Residual energy, Number of past participations, Channel quality or any other similar parameter. A relay is selected only if certain thresholds (like minimum energy level or channel gain) are satisfied which eventually promotes balance. Nodes gain and spend credits based on their participation, discouraging selfish behavior and promoting fair usage. There are certain challenges in ensuring fairness. Sometimes prioritizing in fairness can we have to compromise with throughput or increase delay. Frequently changing channel condition can make fair relay selection difficult.

Incentive mechanisms in relay selection are important as cooperation consumes energy, bandwidth, and time nodes may behave in selfish manner and may refuse to act as relays unless they get their proper incentive. (N. Zhao et. al. 2018) In decentralized mechanism incentives are essential. It may be possible that without incentive the best relays will get depleted first. (Ayub, N et. al. 2019). In credit based mechanism nodes earn credit which can be spent in future for their own transmission. In reputation based mechanism nodes will develop a reputation score which will be helpful in future communication. In auction based mechanism relays will bid for their participation. Transmitting nodes will select best node based on price quote by relay. In certain cases incentives are dependent upon the energy utilized by relay for transmitting cooperative data.

3. System Model

The System model comprises of an access points. There are few nodes which are nearby the access point. There are other nodes which are far from access point and they cannot directly communicate with access point with

greater QoS. So they need the help of intermediate nodes to get high QoS.

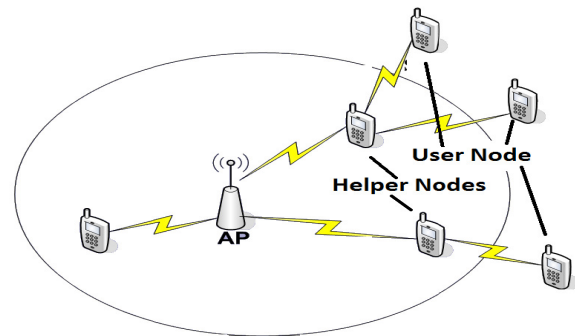


Fig 1 System Model

The nodes which are receiver nodes will transmit the request for data transmission, the request will be overheard by helper nodes. Helper nodes will transmit their cost and offered QoS for data relaying. The receiver node will receive all the cost and offered QoS. It will take decision based on the proposed algorithm.

In proposed algorithm helper broadcasts its residual energy, the data rate it can offer and the price associated with data transmission. The node which needs service will receive all the proposals. Each proposal will be evaluated based on optimization of all three parameters (i.e. residual energy, data rate and cost). Once a helper node is selected it will be given confirmation by user node. User node will also inform access point to transfer data using decided QoS via helper node.

The utility function for helper node is the difference between the price per unit power paid by the secondary user and the cost of the relay, experienced while providing data forwarding service.

$$U_i = p_{ij} * P_{ij} - c_{ij} \dots\dots (1)$$

p_{ij} = price advertised by node i for providing service to node j

P_{ij} = Amount of combination of services purchased by user j from helper i

c_{ij} = Cost of communication

The relay selection will be based on

$$\text{Score} = \alpha * (E_i / E_{\text{max}}) + \beta * (R_i / R_{\text{max}}) + \gamma * (C_i / C_{\text{max}}) \dots\dots (2)$$

α, β, γ are weighting factors

E represent residual energy of the node

C represent cost of the transmission offered by the node

Once a helped node is selected, for the next cycle of cooperation it will increase its cost according to the energy spent on last cooperation assignment. When this criteria is enforced on every node automatically it will enforce the cooperation to shift to other helper nodes. In some cases the QoS will suffer due to fairness in

selection of relay. But overall it will improve the network lifetime. Each node in the network will get maximum benefit out of cooperation.

In our model, we have fixed the job of nodes (i.e. helper nodes and user nodes). In real life the role may get reverse. So at that time the helper node can utilize the cost they have gained for their own data transmission. By this we are ensuring that selfish node will eventually become cooperative nodes.

4. Simulation and results

For simulation, we have used following parameters :

Parameters	Values
Number of nodes	10
PHY layer	WiFi Phy Layer
MAC layer	802.11 b
Band of operation	2.4 GHz
Bandwidth	22 Mbps

we have achieved following results by comparison our relay selection algorithm with cooperative communication and direct communication.

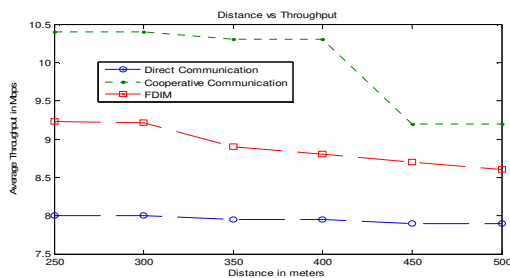


Fig 2 Distance vs Throughput

Figure 2 indicates that cooperative communication offers more throughput than our proposed algorithm. Cooperative communication uses the same relay for cooperation again and again. Due to this unequal utilization of helper node happens which causes less network lifetime.

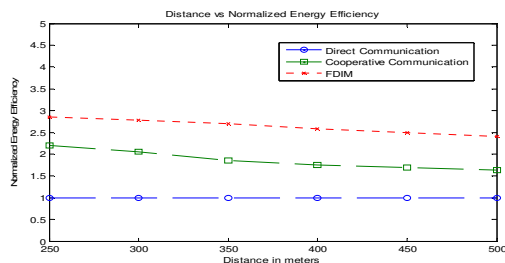


Fig 3 Distance vs Normalized energy efficiency

Figure 3 indicates that our proposed algorithm offers better energy efficiency compared to cooperative communication and it outperforms direct communication. We have considered energy efficiency as one of the decision making parameter in our algorithm.

We have defined a parameter called network lifetime. It is defined as the time till first node in the network goes to 0% of battery. For direct communication it was 172 seconds, for cooperative communication it was 308 seconds. In our proposed algorithm it was 384 seconds.

5. Conclusion

In this paper, we have proposed a novel relay selection strategy which consider fairness based incentive mechanism. Fairness ensures equal use of relay nodes and improved network lifetime. While incentive mechanism ensures that all nodes will get cost for their contribution, which they can utilize in their own communication. By this participation of all nodes is ensured and selfish nodes are also forced to become relay nodes if they want to take advantage of cooperation.

6 REFERENCES:

1. N. Zhao, Y.-C. Liang, and Y. Pei, "Dynamic Contract Incentive Mechanism for Cooperative Wireless Networks," *IEEE Transactions on Vehicular Technology*, vol. 67, no. 11, pp. 10970–10982, Nov. 2018.
2. M. A. Jadoon and S. Kim, "Relay selection Algorithm for wireless cooperative networks: a learning-based approach," *IET Communications*, vol. 11, no. 7, pp. 1061–1066, Mar. 2017.
3. S. S. Kalamkar, A. Banerjee, K. Rajawat, and J. P. Jeyaraj, "Resource Allocation and Fairness in Wireless Powered Cooperative Cognitive Radio Networks," *IEEE Transactions on Communications*, vol. 64, no. 8, pp. 3246–3261, Aug. 2016.
4. S. Abdulhadi, A. Anpalagan, and M. Jaseemuddin, "A Survey of Distributed Relay Selection Schemes in Cooperative Wireless Ad hoc Networks," *Wireless Personal Communications*, vol. 63, no. 4, pp. 917–935, Nov. 2010.
5. Y. Zou, W. Shen, and X. Wang, "Optimal Relay Selection for Physical-Layer Security in Cooperative Wireless Networks," *IEEE Journal on Selected Areas in Communications*, vol. 31, no. 10, pp. 2099–2111, May 2013.
6. Ayub, N.; Rakocevic, V. Cooperative Smartphone "Relay Selection Based on Fair Power Utilization for Network Coverage Extension". *Information*, April 2019.