ANALYSIS OF IMPACT OF GAME THEORY STRATEGIES IN COOPERATIVE WIRELESS COMMUNICATION

[1]*RAVI G. MEHTA,* [2]*RAJNIKANT P. SANDHANI*

[1, 2] **Electronics and Communication Engineering Department,
Government Engineering College,
Rajkot–360005, Gujarat, India.**

ravigmehta@gmail.com

ABSTRACT *: Cooperative wireless communication provides a novel approach by which we can improve resource utilization by utilizing the neighboring nodes to work as Relay. Overall system gains from this scenario. But the node which works as relay has to some of its resources to help other nodes. The scenario needs to be carefully studied because the relay can be cooperative or it can be deflective. Every time the relay will face prisoners dilemma. If certain nodes cooperate and other nodes take advantage of cooperation but do not help when the helper nodes need them then it will give short term benefit to the deflector but in long run it will stop the nodes to be cooperative. Due to this no node will agree to cooperate and we may lose the benefits of cooperation. A mechanism to enforce cooperation amongst nodes is needed. In this paper we have analyzed the impact of deflectors and given the probable solutions by which we can eliminate the deflector nodes.*

KEY WORDS *: Cooperative wireless communication, Game Theory, Strategy of relaying*

1. Introduction

Nowadays wireless communication is essential. The need of data rate is increasing exponentially day by day. The total available spectrum is fixed. So by using these limited resources, we have to serve large number of users who need extreme high data rate. One answer to this problem is Cooperative Wireless Communication. It uses neighboring nodes as relay to transmit the data between distant users. Cooperative wireless communication provides improved data rate, improved coverage area, improved energy efficiency, improved reliability and improved network resource utilization.

Cooperative wireless communication provides many benefits, but it also comes with certain costs and trade-offs. It increases the energy consumption of relay node. It needs time and bandwidth to coordinate about cooperation decision. It requires a complex mechanism to coordinate. (L. Zhao et. al., 2008)

By observing above mentioned advantage, we can say that cooperative scenario is advantageous but the decision of whether to go for cooperation or not should be taken only after carefully studying the cost of cooperation.

Once it is decided that cooperation is best option. The implementation of cooperation depends on how the nodes behave in this scenario. Because when the nodes are used as relay, their energy will consumed to transmit the data of other nodes. It can be beneficial for network but not always beneficial for node. It may be possible that few nodes will use cooperative scenario for their data transmission but they will not help others when their help is needed to transmit others data.

Game theory provides a powerful framework for analyzing strategic decision-making in cooperative wireless communication systems. It can be applicable in :

- Resource allocation: Modeling how nodes compete for limited network resources like bandwidth, power and time slots.
- Relay selection: Analyzing how nodes choose cooperative partners to optimize overall network performance.
- Power control: Determining optimal transmission power levels to balance energy efficiency and interference.
- Coalition formation: Analyzing how nodes form cooperative groups to improve network efficiency.
- Pricing and incentive mechanisms: Designing schemes to encourage cooperation among selfish nodes.

These game-theoretic models can be useful to design more efficient, fair and robust cooperative wireless communication systems. (W. Saad et. al., 2009)

A mechanism must be defined by which the nodes which are cooperating must be protected against the selfish node. In this paper we have analyzed the scenario which shows the impact of selfish node on the performance of cooperative nodes. We have also discussed a mechanism by which selfish behavior can be curbed.

An excellent example of bats in a cooperation scenario is reciprocal altruism in vampire bats. They use it in Food Sharing. Vampire bats feed on blood, but sometimes they fail to find a meal in a night. A bat that goes two or three nights without feeding can starve to death. Well-fed bats often regurgitate blood meals to feed hungry roost-mates who failed to find food. This behavior is a form of reciprocal altruism: The donor bat incurs a cost (loss of some nutrition). The recipient gains a life-saving benefit. In the long term, bats remember who helped them and are more likely to return the favor later. This builds a mutual aid network within the colony.

Analysis of Prisoner's Dilemma can be useful in analyzing the node's decision of whether to cooperate or not.

2. Prisoner's Dilemma

The prisoner's dilemma scenario in wireless communication can be applied to various aspects of network operation and resource management. This concept provides a framework for understanding the complex decision-making processes that occur within wireless networks, where individual nodes must balance their own interests against the overall efficiency and performance of the system. The key applications are :

1. Power control: Nodes in a wireless network must decide whether to transmit at high or low power levels. Transmitting at high power can improve individual performance by increasing signal strength and range. However, this choice also increases interference for other nodes in the network. Conversely, transmitting at low power reduces interference but may compromise individual performance. This creates a dilemma where each node must weigh the benefits of improved personal performance against the potential negative impact on the overall network.

2. Spectrum sharing: In scenarios where multiple users or devices share the same frequency spectrum, they face a choice between cooperative and selfish behavior. Users can choose to cooperate by efficiently sharing the available spectrum, which benefits the entire network but may limit individual throughput. Alternatively, they can act selfishly by attempting to monopolize spectrum resources, potentially improving their own performance at the expense of others and overall network efficiency.

3. Relay cooperation: In multi-hop wireless networks, nodes have the option to assist in relaying data for other nodes. This cooperation improves overall network performance by extending coverage and reducing energy consumption for distant nodes. However, acting as a relay consumes energy and computational resources, creating a dilemma for each node between conserving its own resources and contributing to the network's collective benefit.

4. Channel access: In wireless networks, nodes must contend for access to communication channels. They can either follow cooperative medium access protocols, which ensure fair and efficient channel utilization, or attempt to monopolize channel access for their own benefit. The latter approach may provide short-term gains for individual nodes but can lead to congestion and reduced overall network performance. (S. Bharati and W. Zhuang, 2013)

5. Data forwarding: In multi-hop networks, nodes face a dilemma when it comes to forwarding data packets from other nodes. Cooperating by forwarding others' packets contributes to the network's functionality and extends its reach. However, this behavior consumes energy and bandwidth that could otherwise be used for the node's own transmissions. Nodes must balance the benefits of network cooperation against the conservation of their own resources. (L. Ferdouse et. al. 2019)

6. Coalition formation: Wireless devices have the option to form cooperative groups or coalitions to improve efficiency and performance. These coalitions can lead to better resource utilization, improved coverage, and enhanced overall network capabilities. However, joining a coalition may require compromises in individual autonomy and resource allocation. Nodes must weigh the advantages of collective action against the potential limitations on their independent operation.

7. Resource allocation: In wireless networks with limited resources such as bandwidth, time slots, or computational capacity, nodes must decide how to allocate these resources. They can either share resources equitably, promoting overall network efficiency, or attempt to hoard resources for their own use. This creates a tension between individual optimization and collective benefit. (R. Q. Hu and Y. Qian, 2014)

In each of these scenarios, individual nodes face a dilemma between cooperating for the greater good of the network and acting selfishly for short-term individual gain. This tension mirrors the classic prisoner's dilemma, where the collectively optimal outcome may differ from what is individually rational. (Z. Han et. al. 2011)

The application of game-theoretic analysis to these wireless communication dilemmas can provide valuable insights into node behavior and network dynamics. Game theory offers tools to model and analyze the strategic interactions between nodes. It helps in understanding the potential outcomes of different strategies and behaviors. Furthermore, game-theoretic analysis can inform the design of incentive mechanisms and protocols that encourage cooperative behavior among network nodes. These mechanisms can help align individual node interests with the overall network objectives, leading to more efficient and robust wireless communication systems. By carefully crafting rules, rewards, and penalties, network designers can create environments where cooperation becomes the dominant strategy, even when individual nodes are primarily concerned with their own performance.(P. O. Toups Dugas et. al. 2014)

3. NODE BEHAVIOUR

Game theory concepts from the Prisoner's Dilemma can be applied to cooperative wireless communication, providing valuable insights into node behavior and network performance. This application extends beyond simple cooperation and defection, encompassing various strategies that nodes can adopt to optimize their performance and resource utilization.

1. Tit for Tat: This strategy involves nodes initially cooperating and then mimicking the previous action of their partner. If a node cooperates by forwarding packets, the partner reciprocates in the next round. Conversely, if a node defects by not forwarding, the partner also defects in the subsequent interaction. This approach promotes cooperation while allowing for retaliation against selfish behavior. It can lead to stable cooperative relationships between nodes, enhancing overall network efficiency.

2. Unforgiving: In this strategy, once a node defects, the partner permanently stops cooperating. This approach aims to punish selfish behavior harshly, deterring nodes from exploiting others. While it can effectively discourage defection, it may lead to long-term network fragmentation if multiple nodes adopt this strategy and cease cooperation after isolated incidents.

3. Cooperate: Nodes always forward packets for others, prioritizing overall network performance. This strategy maximizes network throughput and connectivity but risks exploitation by selfish nodes. In a network where all nodes adopt this strategy, performance would be optimal, but it may not be sustainable if some nodes prioritize individual gains over collective benefits.

4. Defect: Nodes never forward packets for others, focusing solely on conserving their own resources. While this strategy may benefit individual nodes in the short term, it can significantly degrade overall network performance, potentially leading to isolated network segments and reduced connectivity.

In cooperative wireless networks, these strategies manifest as follows:

- Cooperation: Nodes actively participate in packet forwarding for others, contributing to improved overall network throughput and connectivity. This behavior enhances the network's ability to handle diverse traffic patterns and maintain robust communication links across the entire network topology.

- Defection: Nodes refuse to forward packets for others, prioritizing the conservation of their own energy and computational resources. While this may extend the lifespan of individual nodes, it can have detrimental effects on the network as a whole, potentially isolating parts of the network and creating communication bottlenecks. (H. Chen et. al., 2015)

4 SIMULATION & RESULTS

In simulation setup we have used an area of 100 m * 100 m. In this area we have four type of strategy for nodes i.e. cooperative nodes, tit-for-tat nodes, unforgiving nodes and defecting nodes. The nodes are distributed randomly and they interact with each other. Their decision of operation depends upon the strategy they have adapted. In most of the simulations more than 1000 interactions are considered between nodes.

In first simulation we have used 10 cooperating nodes, 10 tit for tat nodes and 2 defection nodes. In next simulation the defection nodes have been increased to 5 and 10. In each case it has been observed that as the number of defection nodes are increasing the payoff for cooperative nodes gets reduced, which can be highly frustrating for the nodes who are cooperating. This can lead to denial for cooperation.

To solve the above mentioned problem, we have introduced unforgiving nodes, who will not cooperate with the selfish nodes. So when we have increased these nodes from 5 to 10, the payoff of selfish nodes reduced drastically and cooperative nodes have increased. So unforgiving policy ensured that cooperation is the best policy.

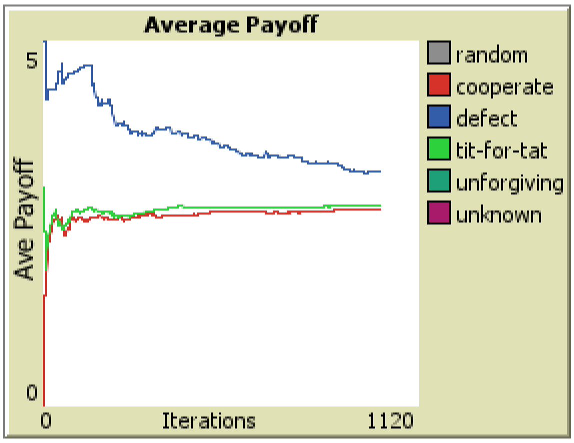

Fig. 1 (2 defecting nodes)

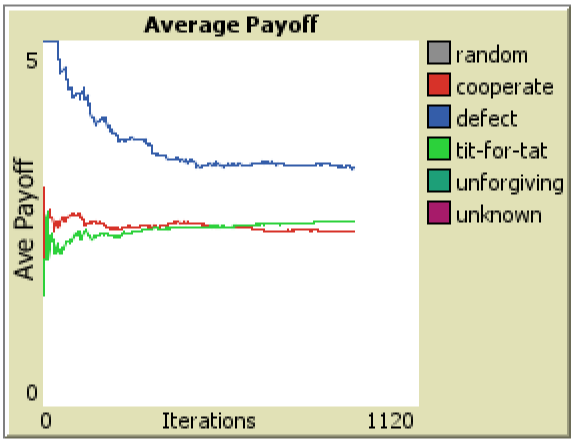

Fig. 2 (5 defecting nodes)

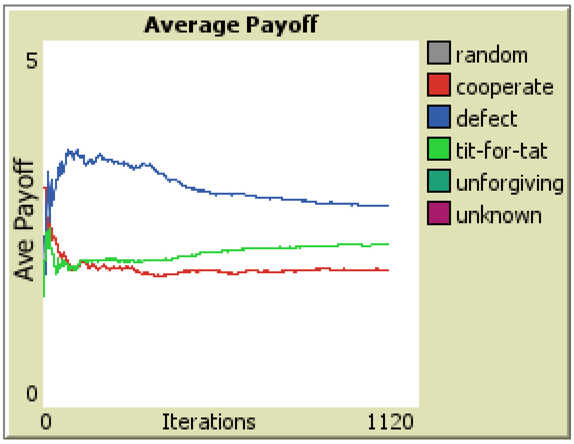

Fig. 3 (10 defecting nodes)

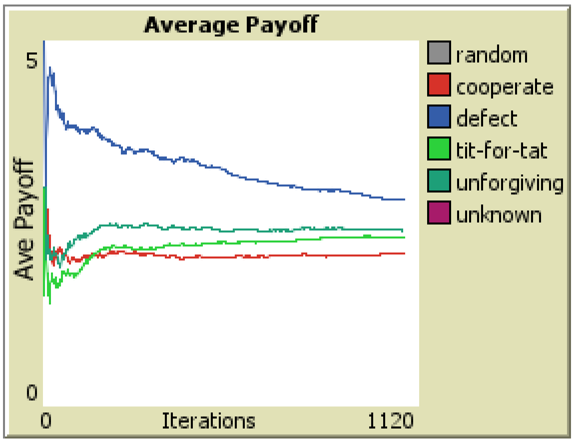

Fig. 4 (10 defecting nodes, 5 unforgiving nodes)

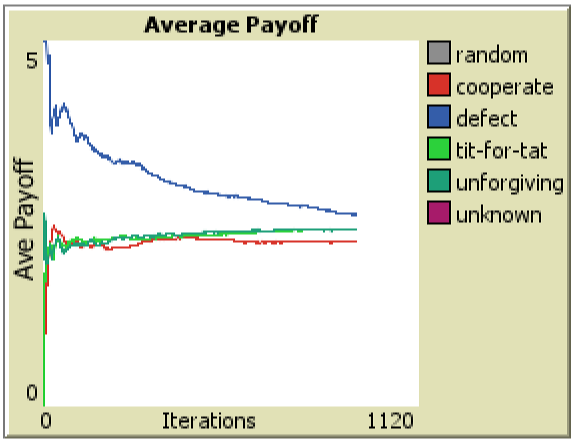

Fig. 5 (10 defecting nodes, 10 unforgiving nodes)

5 CONCLUSION

In this paper, we have proved that cooperation is excellent strategy for network performance. But individual nodes has to give away selfish behavior for overall network performance. If some node uses others for cooperation but does not provide relaying facility then cooperation mechanism will collapse. To sustain cooperation scenario, we have to include some policies which will identify and take punitive action against selfish nodes.

6 REFERENCES

1. L. Zhao, H. Zhang, and J. Zhang, "Using Incompletely Cooperative Game Theory in Wireless Mesh Networks," *IEEE Network*, vol. 22, no. 1, pp. 39–44, Jan. 2008

2. L. Ferdouse, A. Anpalagan, and S. Erkucuk, "Joint Communication and Computing Resource Allocation in 5G Cloud Radio Access Networks," *IEEE*

Transactions on Vehicular Technology, vol. 68, no. 9, pp. 9122–9135, Jan. 2019

3. P. O. Toups Dugas, W. Graves, A. Jarrah, W. A. Hamilton, O. Garretson, and J. Hammer, “A framework for cooperative communication game mechanics from grounded theory,” Oct. 2014, pp. 257–266.

4. R. Q. Hu and Y. Qian, “An energy efficient and spectrum efficient wireless heterogeneous network framework for 5G systems,” *IEEE Communications Magazine*, vol. 52, no. 5, pp. 94–101, May 2014.

5. W. Saad, Z. Han, A. Hjorungnes, T. Basar, and M. Debbah, “Coalitional game theory for communication networks,” *IEEE Signal Processing Magazine*, vol. 26, no. 5, pp. 77–97, Jul. 2009.

6. Z. Han, A. Hjørungnes, D. Niyato, T. Başar, and W. Saad, “Game Theory in Wireless and Communication Networks,” cambridge university, Oct. 2011.

7. S. Bharati and W. Zhuang, “CAH-MAC: Cooperative ADHOC MAC for Vehicular Networks,” *IEEE Journal on Selected Areas in Communications*, vol. 31, no. 9, pp. 470–479, Sep.

8. H. Shan, H. Cheng, and W. Zhuang, “Cross-Layer Cooperative MAC Protocol in Distributed Wireless Networks,” *IEEE Transactions on Wireless Communications*, vol. 10, no. 8, pp. 2603–2615, Aug. 2011.

9. H. Chen, J. Luiz Rebelatto, B. F. Uchoa-Filho, Y. Li, and B. Vucetic, “Harvest-Then-Cooperate: Wireless-Powered Cooperative Communications,” *IEEE Transactions on Signal Processing*, vol. 63, no. 7, pp. 1700–1711, Mar. 2015.