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Optimization Techniques in Cooperative and Distributed MAC Protocols:
A Survey

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ABSTRACT

The tremendous increase in wireless network application finds distributed allocation of resources allocation very useful in the network. Packet delivery ratio and delay can be improved by concentrating on payload size, mobility, and density of nodes in the network. In this article, a survey is carried out on different cooperative and distributed MAC protocols for communication and optimization algorithms for various applications and the mathematical issues related to game theory optimizations in MAC protocol. Spatial reuse of channel improved by (3-29) % and multi-channel improves throughput by 8% using distributed MAC protocol. The energy utility of individual players can be focused to get better network performance with NASH equilibrium. Fuzzy logic improves channel selection by 17% and secondary users' involvement by 8%. Jamming, interference problems can be addressed using cross layer approach in the MAC and simultaneous data, voice transmissions in IoT; WSN applications can be attained using hybrid distributed MAC protocol.

KEYWORDS

Congestions, Cooperative and Distributed MAC, Game Theory, Nash Equilibrium, Traffic and Energy

1. INTRODUCTION

ATMA, Queen-MAC and advertisement MAC are simulated in (Swain et al., 2017) and obtained better performance in advertisement MAC with PDR about 90%. Spatial reuse of the channel is improved by (3-29)% in distributed MAC compared to multi-channel MAC (Wu, C. M. et al., 2017), throughput improved by 8.9% and outage probability of primary users improved from 55% to 41%. Energy efficiency is 84% with optimizing the link quality and energy efficiency is 90% by optimizing BER, data packet size (L. T. et al., 2011). Unscented summation in information consensus filter (ICF)

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performs better than the scented ICF and gives a chance of 99.7% for the existence of true state for the node (Yao, P. et al., 2019).

In harsh environments, the possibility of change in node positions and link quality are more, a link aware and score based protocol is proposed to increase lifetime (Manikandan, A. et al., 2023). A hill climbing algorithm with distributed and environment driven conditions is proposed to have trade-off between energy and lifetime in the network (Yaman, A. et al., 2023). Cryptosystem with public key and homomorphism encryption controls the data security and authentication in wireless networks (Kalyani, G. et al., 2022). In vehicular ad hoc networks voice over internet plays major role. It also faces challenge to transmit voice with high quality. Packet loss, jitter and delays are to be addressed for high QoS (Dafalla, M. E. M . et al., 2022). Q learning algorithm which is distributed in satellite networks and improving its learning efficiency to improve delay, throughput and sum rate (Rwandamuriye, F. X. et al., 2023). Speed of transmission is always a concern in underwater optical networks for which TDMA with distributed nature and cross layer cluster approach with multi-slots are enforced (Huang, J. et al., 2023). Bio medical sensor nodes demand allocated or dedicated time slots as they are heterogeneous themselves and it is difficult to sense and monitor a patient information in the long run to capture information in contention free phases (Masud, F. et al., 2023).

Wireless traffic and the abnormality are addressed by using wireless sniffers which are assigned for each channel in a multi-channel network and hence capture data packets in spite of unreliability in channel conditions (Bahrami, E. et al., 2023). Wireless sensor networks are made of sensor nodes which are self configured and preferable to have smart computing for various applications and in various fields. Node energy had been always a challenge for which density and scalability of nodes play major role (Santhosh, G. et al., 2023). Channel collisions are resolved using two coding techniques in two layers namely LDPC codes and algebraic codes. Low complexity in the algorithm and smaller gap to achieve the expected capacity using these codes (Macintosh, J. et al., 2023). Aerial base stations draw attraction in recent times for cellular networks. These aerial networks are drone carried and must be maintained and monitored accordingly which need additional effort like taking care of line of sight problems are introducing more number of drones (Arribas, E. et al., 2023). Cloud technology with IoT connected devices like detectors, RFID, controllers and 3G networks by improving processing and capacity to improve data skew rate and decrease complexity of the interconnections (Raghavendar, K. et al., 2023).

Solutions for techo-economic analysis is given using present value, traffic intensity for fibre optic wireless networks (Breskovic, D. et al., 2019). A discount of (10-15) % is given for corporate projects, (25-30) % discount for high start-ups and 10% discount for remaining projects. Adaptive Q learning shows 41% lesser delay and 51% more residual energy compared to other methods (Alarifi, A. et al., 2019). Faults in network on chip (NoCs) are addressed using distributed and adaptive routing algorithms (Nehnouh, C. et al., 2019). This method is deadlock free and does not use any virtual channels or routes. Initially selects the route based on state of the link, later based on traffic and congestion, it selects the adjacent routers in second step. Faults are reduced to 0% and latency reduced by 19.4% in this distributed and adaptive routing algorithm.

RPL protocol divides the data to be transmitted with reference to the parameters using wolf and fuzzy optimizations (Wang, Z. et al., 2023). Synchronization cycle optimization is concentrated using backoff component which prevents collision in the network (Uthayakumar, G. S. et al., 2023). Multi-agents can have decentralized learning only if there is continuous transfer of information over the channel. When there is delay and uncertainty in the communication, based on data available at the agents will degrade the performance and is called age of information (AoI) (Redder, A. et al., 2022). A smart home design is aimed with cooperative communication between power line of hybrid nature and visible light for communications. Physical layer is designed but MAC layer faces a lot of problems in design (Sheng, H. et al., 2022).

Saturated, unsaturated traffic conditions are considered to carefully optimize node performance without having adverse effect on network performance. Game theoretical approach is used to present a realistic approach even with incomplete information to improve network performance (Dudhedia, M. A. et al., 2022). MIMO and OFDMA are popular for cellular networks, however when applied to Wi-Fi there exists challenges in optimizing the airtime overhead parameter for applying OFDMA to 802.11ax for the first time (Wang, H., et al., 2023). Feed forward and deep networks with buffalo optimization in routing is used to handle data aggregation efficiently and routing in multi-path for wireless sensor networks. Memory and computational power are in adequacy for sensor networks which increases delay, decrease packet delivery ratio (Rani, S. S. et al., 2023). Intelligent computing techniques have a list of bio inspired optimization techniques namely grey wolf, particle swarm, genetic algorithm and artificial bee colony methods (Sarkar, T. et al., 2022).

The rest of the paper is presented as: Section 2.1 narrates different approaches of distributed MAC for nodes in accessing the channel parallelly, Section 2.2. elaborates various optimization methods for MAC and Section 2.3 explains game theory optimization and other state of art algorithms to improve different performance metrics of the network. Section 3 concludes with different other works and observations in the same and relevant directions.

2. SURVEY OF VARIOUS OPTIMIZATION TECHNIQUES IN MAC

2.1 Distributed MAC

Distributed cooperative, cross layer logics in MAC helps in clearing optimization problems in single hop and multi-hop operations in network (Shamna, H. R. et al., 2017). A non-cooperative interference channel frequency selective game suitable for all types of channels like Rayleigh, racian etc is proposed in (Bistritz, I. et al., 2018) for artificial utility rate of each user. Cross layer approach helps in overcoming unreliability problem when topology changes and routing decisions are in chaos (Jembre, Y. Z. et al., 2018). Data nodes and voice nodes try to access the channel in the contention free period and the problem starts. Managing data collection in a heterogeneous environment using a non-linear cooperative approach (Casado-Vara, R. et al., 2018) for temperature data collection from indoor surfaces.

Reservations in time slot are not disturbed but still successful in cooperation collision avoidance (Bharati, S. et al., 2016). Back off algorithm with randomization in accessing the channel do not reduce the number of collisions, decrease throughput and contention window size based on number of successfully sent data (Al-Hubaishi, M. et al., 2014). Randomized routing paths which are diversity in nature provide location privacy for source node and thereby increase the safety period and increase the attacker node back tracking period (Raja, M. et al., 2018).

Evolutionary optimization need central coordination, however without a central coordination and by using a hill climbing algorithm the network performance and energy consumption are monitored using a 3-stage TDMA technique (Yaman, A. et al., 2023). Age of information (AoI) is caused due to delay and uncertainty in data communication which is addressed by a representative model with signal to interference noise (SINR) into consideration. Fading, shadowing, interference and noise are given preference in designing the representative model and ergodic Markov chain with geometric characteristics to deal the agent mobility during data communications. These help in controlling AoI growing asymptotically and converge the distributed algorithms (Redder, A. et al., 2022). Wireless sniffers are used to capture data packets in wireless channel; however assigning one sniffer to each channel depends on the availability of number of sniffers. Unknown user and their behaviours are addressed using centralized, distributed algorithms which use sniffer and channel assignments redundantly and find balance between coverage, exploration, channels assigned and accuracy in the network (Bahrami, E. et al., 2023).

Table 1 discusses various distributed MAC protocols – approaches used by other authors.

Eigen value dependance on boundary conditions can be avoided by separating the transfer function models (Rabenstein, R. et al., 2018). Trade off between the parameters energy efficiency and QoS are addressed using multi-channel namely advertisement channel and data channel and switching

Table 1. Various distributed MAC protocols: Approaches used

Authors	Type of MAC	Approaches	Achievement
(HR Shamna et al., 2017), (Lakshmi P et al., 2019)	EECO-MAC	relay node selection, cross layer	throughput and lifetime
(Sailesh Bharati et al., 2016)	Cooperative Ad hoc (CAH-MAC)	Channel fading, node relative mobility	Reliability, throughput
(Weihua Zhuang et al., 2016)	DAH-MAC	Voice transmission-TDMA, data-CSMA	Throughput optimization
(Chih-Pin Lo et al., 2017)	Distributed MAC	Markov Chain Model less outage probability	throughput, spatial reuse
(Yingsong Huang et al., 2014)	Distributed PS-MAC	Service policies, different traffic model	Better overhead, throughput
(M. Al-Hubaishi et al., 2014)	Distributed 802.11 MAC	Slotted backoff binary exponential algorithm	Fairness index
(Guoyang Yan et al., 2018)	Distributed network control	Multivariate MV bench marks	Delays – system, communication
(Per Kreuger et al., A. Pietrabissa et al., 2018)	Dynamic and distributed systems	Compute target values - load balancing actions	ControlProbabilistic overload

dynamically between the channels (Swain, R. R. et al., 2017). Distance between secondary users and the transmitter power helps in spatially reuse of the channel and thereby increases throughput and outage probability for primary users for cognitive ad hoc networks (Wu, C. M. et al., 2017). Physical networking layer coding (PNC) is used to improve the performance in throughput sensitive applications for WSN (Wang, S. et al., 2012).

Dynamically changing channel conditions can be accessed using adaptive and distributed method in resource allocations via an optimal mixed strategy and game theory approach (Song, T. et al., 2018). The adaptive and distributed MAC helps in monitoring the situation, adjusting contention window and exploiting the traffic multiplexing (Ye, Q. et al., 2016). Power constraints in under water sensor network is addressed using optimization in data packet size and their related look up tables (Jung, L. T. et al., 2011).

Based on delay d in the transmission of frames of N nodes, the fairness index is calculated as:

$$f\left(d_1, d_2, d_3, \ldots, d_N\right) = \frac{\left(d_1 + d_2 + d_3 + \ldots + d_N\right)^2}{N\left(d_1^2 + d_2^2 + d_3^2 + \ldots + d_N^2\right)} \tag{1}$$

In a multi-channel if the power of a signal in one of the channel is $x_{p,}$ overlaps with another channel whose signal power is x_q; interference of channel p over channel q is x_p/x_q. Utility matrix can be calculated with gain and loss functions. Gain function tells of throughput attained by player n where loss function tells cost of all other players in the game with respect to player n. Malicious behavior of node may exist if a node is not following rules in game theory or trying to achieve throughput irrespective of all other nodes. Table 2 presents multichannel / conventional MAC, various approaches used.

Gain function is normally calculated as:

$$u_{n,g}\left(a_{n,p}, aJ_{n,q}\right) = BW\left(a_{n,p}\right) * \log_2\left[1 + \left\{\left(1 - I_x\left(a_{n,p}, aJ_{n,q}\right)\right) * SNR\left(a_{n,p}\right)\right\}\right] \tag{2}$$

Table 2. Multichannel / conventional MAC: Approaches used

Authors	Type of MAC	Approaches	Achievement
(Rakesh Ranjan Swain et al., 2017)	Adv-MM MAC	Dynamic switching of nodes among channels	Better energy, PDR, EED
(Yalew Zelalem Jembre et al., 2018)	MAC for channel assignment	Cross layer, dynamic channel assignment	less Interference, congestion
(Shiqiang Wang et al., 2012)	CSMA extension to 802.11 MAC	Physical layer network coding (PNC)	Throughput improvement
(Taewon Song et al., 2018)	Increase APs in WLAN - ADRA	Game theoretical approach	More throughput and fairness
(Seema Ansari et al., 2015)	Contention free/based MAC	Various MAC for UWSN	Error probability, BW
(Low Tang Jung et al., 2011)	ALOHA-UWSN	Optimal packet length	Higher throughput, η_E
(Ching-Han Chen et al., 2017)	802.15.4 MAC -WSN	ARMA lattice filter algorithm	Increased PDR
(Peng Yao et al., 2019)	Information fusion model in sensors	Weighted consensus non linear filter-WCF	Scalability, tolerance in netw
(Peng Yao et al., 2018)	State estimation -no fusion node	Average information WCF	Scalability, tolerance in netw
(Alexandre T. Oliveira et al., 2021)	SDN architecture	Network controller	Met QoS requirements

where $I_x\left(a_{n,p}, aJ_{n,q}\right)$ shows I-factor overlap for row player n performing p pure strategy while transmission, column player J_n performing q pure strategy while reception.

Loss function is calculated as:

$$u_{n,l}\left(a_{n,p}, aJ_{n,q}\right) = -I_S\left(aJ_{n,q}, a_{n,p}\right) * RJ_n \quad (3)$$

where $I_S\left(aJ_{n,q}, a_{n,p}\right)$ shows I-factor overlap for row player J_n performing q pure strategy while transmission, column player n performing p pure strategy while reception.

GRAFCET is introduced in (Chen, C. H. et al., 2017) to overcome the reliability and communication bandwidth problems in 802.15.4 MAC. PDR was obtained as 100% by introducing GRAFCET for WSN applications instead of 802.15.4 MAC. Each data flow can be monitored and QoS negotiations can be carried out between controller and applications using SDN architecture (Oliveira, A. T. et al., 2021). Memory utilization was 30% and CPU consumption stayed at 25% in this SDN. An intelligent system is designed using artificial intelligence methods to address the malicious nodes and insufficient information problems in a network (Kotenko, I. et al., 2020). The architecture uses components for data collection, timely analysis, proper classification.

Visible light for communications, power line of hybrid nature are used as cooperative communications in a smart home design. Combining 1901 IEEE standards and 802.15.7 with carrier sense and additional assistance for channel allocation related strategies will help in attaining minimum error, fading and noise in MAC design (Sheng, H. et al., 2022). Traffic prioritization which is contention based is followed in body area networks and using heterogeneous group of sensor nodes which find difficult to capture data in contention based traffic and hence dedicated time slots are allocated to them. So, beacon enabling is followed in 802.15.4 and 802.15.6 IEEE Mac protocols to extend the body of knowledge for the sensor nodes thereby they transmit data in phases (Masud, F. etal., 2023). Sensor nodes used in underwater optical networks are enabled for cross layer cluster approach with multi-slot MAC protocol so that collisions can be estimated and detected dynamically with the help of TDMA distributed protocol. Nodes are capable of storing cluster information of surrounding nodes and their slot occupancy with the help of routing techniques to improve throughput and reduce collisions (Huang, J. et al., 2023).

Distributed polling service MAC can help in design considerations and challenges (Huang, Y. et al., 2014). Transmission delay is obtained around 70% percent of the total transmission latency. Time delays and communication delays are monitored and adjusted using distributed logic for networked control systems (Yan, G. et al., 2018). Results of DNCs for motivating the decentralized control systems.

Faster convergence, low energy and optimize positioning of nodes are achieved using PSO algorithm (Yan, Z. et al., 2019). D-S evidence trust theory, preprocessing and optimal solution parent mechanisms help to increase the trust degree of evaluate nodes (Sun, Z. et al., 2019). Optimal partition can be done based on energy of nodes, later convergence can be achieved using neural network optimization method (He, Y. et al., 2018). Barrier coverage problem in WSN is addressed using linear, non-linear and optimization via simulation methods in which OVS address more realistic problems (Karatas, M. et al., 2019). Based on bandwidth optimization, traffic load and channel capacity in the network, a maximum hop number is determined using traffic based scheduling (Liao, Z. et al., 2015). Flow control, power control and scheduling at each node is taken into consideration and achieved minimum energy with trade-off in queue delay (Tsoukatos, K. P. et al., 2017). Taking the constraints into account, a scheduling is designed with block structured process and logic programming based on constraints (Bădică, A. et al., 2020).

Aerial base stations for cellular networks draw its attention onto fairness metric and the convex problem which mixed integer and intractable in nature. Resource scheduling and drone relay stations are introduced to handle the fairness metric in aerial base stations (Arribas, E. et al., 2023), (Radha, S. et al., 2020). Relay nodes are randomly selected by cluster head according to the distributions probability and achieving data transmission with low deployment cost using a random relay matrix. Fixed cluster head and random relay nodes avoids the inefficient inter- clusters communications of traditional method (Luo, X. et al., 2023). IoT connected devices like 3G networks, GSM, detectors and controllers are cloud monitored for their resource allocation and utilizing the resources effectively. Minimizing the operational expenses, improving processing capabilities and utilization of IoT services are challenging which improve skew rate performance, decrease complexity and challenges in the consumption rate (Raghavendar, K. et al., 2023).

Proper handling of scheduling in IIoT applications can help in higher throughput, lower energy consumption. Rapid changes in topology and delay targets can be controlled using TDMA in data link layer and thereby increase efficiency, adaptability in the network (Kherbache, M. et al., 2022). Latency, data freshness and data accuracy, temporal correctness and given importance in data aggregation. It is not simple but needs efficient and meaningful logics which are concentrated and addressed via proper design of interference, network topology and mobility, fault tolerances in the IoT, WSN networks (Begum, B. A. et al., 2023). Introducing power splitting, selective time switching type of relays with cross layer approach led to decode and forward logic in cooperative communication for networks. Shadowing, path loss and fading which makes the communication link unreliable are addressed by these methods (Akande, D. O. et al., 2020).

If link quality is good, energy efficiency can be maintained even with high packet length. So, higher payload can support higher throughput. Look up table / graph is analyzed to fix optimization parameter to obtain optimal energy efficiency.

Energy efficiency is given by:

$$\eta_E = \frac{Actual\ packet\ length\left(in\ bits\right)}{Total\ Packet\ length\left(in\ bits\right)}\left(1 - Packet\ error\ rate\right) \tag{4}$$

Energy per useful bit is given by:

$$E_{bit} = \frac{E_{e2e}}{P_L\left(1 - PER_{e2e}\right)} \tag{5}$$

where P_L is the payload length, E_{e2e} is the energy consumption from end-end, PER_{e2e} is the packet error rate from end-end.

2.1.1 Inferences From Distributed MAC Protocols

- Enhanced cooperative ad hoc network achieves better reservations in time slots with minimum problems of collision with 2 hop neighbors using Jake's vhannel model and nakagami distribution, distributed MAC using TDMA by avoiding relay transmission phase in CAH-MAC.
- Simultaneous data, voice transmissions simultaneously for IoT applications can be obtained using adaptive hybrid distributed MAC.
- Gated, exhaustive and limited k services in distributed service policies are used for controlling overhead problems in MAC. Different short range traffic related models like on off bursty, long range dependent (LDR) and IID Bernoulli are applied for better performance in wireless networks.
- 802.11 for ad hoc has single channel in MAC and multi-channels for physical layer to face hidden terminal problems that occur in MAC layer.
- Contention window size variations can be done based on successful number frames getting transmitted in 802.11 MAC in order to get better delay, throughput and packets drop in wireless mobile ad hoc type of networks.
- Jamming problems, congestion and intereference in MAC layer can be handled using dynamic channel and cross layer approach in the network.
- Idle listening leads to wastage of energy, it can be avoided by introducing advertisement packet which tells of the free channels available for data transmission by the nodes.
- Fairness index of a network can be improved using back off algorithm in binary exponential fashion. Enhanced back off and improved back off further improves the performance.
- Physical Layer Network coding (PNC) allow multiple nodes transmitting data simultaneously; however it is difficult to handle in multi hop scenarios. PNC may not be always an advantage; it has to work in compatible with conventional network coding (CNC) and conventional relay schemes.

2.2 Optimization Algorithms

Non linear inertial weight is adopted to overcome the local optimum in binary PSO and thereby increases convergence rate, low task period and energy.

Energy per bit is given by:

$$E = \frac{0.5 * \log_e 2}{R} \tag{6}$$

where R is the radius of the network, 0.5 is noise variance.

As energy is not considered as the major analysis, the low energy nodes fail if they send more packets. It is addressed using congestion control algorithm with heuristic methods rather than Poisson methods (Singh, K. et al., 2018). Throughput is higher and delay is lower in the hybrid multi-objective congestion control algorithm compared to cuckoo and adaptive cuckoo search algorithms. Relay selection based on interference aware in the path and decomposing the problems into convex optimizations for accessing the link rate and node transmit power optimization, reliability (Fan, X. et al., 2021).

A multichannel MAC with CSMA for data exchange and TDMA, FDMA for collision free in network is proposed to handle dynamic positions of nodes and link quality in harsh environments. Fuy clustering and flower optimizations are combined to identify malicious nodes and get rid of them to increase network lifetime, performance (Manikandan, A. et al., 2023). MAC protocol helps in decreasing the depletion methods by using back off exponent to prevent collisions, optimizing synchronous cycle using SMAC and thereby controlling energy constraint in the network (Uthayakumar, G. S. et al., 2023). Link state routing protocol is optimized for transmitting voice over internet in spite of challenges in delay, jitter and packet loss in the channel. Multi-hop ad hocs are used with 2 hops and 4 hops to get over the challenges and achieve quality of service in transmitting voice over internet in the vehicular ad hoc networks (Dafalla, M. E. M. et al., 2022). Energy optimization in sensor networks found a new path to handle using artificial bee colony algorithm without the necessity of density and traffic of nodes. Instead, mutation and cross over techniques are used to optimize energy by selecting low energy node as head in the clusters. Cauchy operator and grenade explosion helps in fixing fitness and energy efficiency for data collection (Santhosh, G. et al., 2023).

An adaptive Q- learning machine learning algorithm helps in achieving minimum overhead, improves the communication in inter and intra-clusters by increasing number of live nodes (Alarifi, A. et al., 2019). Energy efficient clustering with genetic algorithm is introduced for static, optimal clustering in first step and then cluster head selection for minimum energy consumption and using genetic algorithm twice in the process (Singh, S. P. et al., 2018), (Subramanyam, R. et al., 2022). Minimum exposure problem is addressed by PSO with hybrid genetic algorithm (Aravinth, S. S. et al., 2021). HMM the hidden markov model helps in increasing lifetime and minimum energy consumption in this process.

In PSO, the performance of nodes or particles in d-dimensional space is calculated using fitness function as:

$$V_i^d\left(t+1\right)=WV_i^d\left(t\right)+k_1r_{i_1}\left(P_{besti}{}^d-POS_i^d\left(t\right)\right)+k_2r_{i2}\left(G_{best}{}^d-POS_i^d\left(t\right)\right) \tag{7}$$

$$POS_i^d\left(t+1\right)=POS_i^d\left(t\right)+V_i^d\left(t+1\right) \tag{8}$$

where V_i^d is the velocity of i^{th} particle in d-dimension, P_{best} is the best position of the particle previously, G_{best} is the best solution of the particle globally, POS is the position of each particle, k_1 and k_2 are the cognitive and social parameters, r_{i1} and r_{i2} are the random values between 0 and 1.

The velocity of the particles is calculated as:

$$V_i^d\left(t+1\right)=r_iV_i^d\left(t\right)+a_i^d\left(t\right) \tag{9}$$

The position of the particle or node is calculated as:

$$POS_i^d\left(t+1\right) = POS_i^d\left(t\right) + V_i^d\left(t+1\right) \tag{10}$$

Hybrid method ACO PSO algorithm provides way for cluster formation, then the inter cluster communication starts after data aggregation which shows better lifetime in the network (Kaur, S. et al., 2018). It improves throughput by 2.7%. Cooperative communication brings energy efficiency but clustering based cooperative communication doesn't contribute for increasing lifetime. Transceiver optimization with distributed MAC can help for best next hop selection and thereby give better energy efficiency and network lifetime (Kakhandki, A. L. et al., 2018). It provides 86% improvement in lifetime, overhead by 32% decreased and 82% node decay rate reduction.

Sensing matrix and node matrix algorithms address the chaos situations to achieve secure data transmission of sensed packets, hence the recovery rate is 100% and attacks are detected where the success rate obtained is 98%, relative error is 10% with compression rate in encryption is 40% (Lu, W. et al., 2013). Searching for optimal method in attack the localization, then task allocation helps in better energy consumption than the conventional PSO method (Sun, Z. et al., 2018). ALTA gives 98% load balance whereas the conventional PSO gives only 77% load balance. ALTA provides 15% reduction in the distance value than the conventional methods while task allocation is carried out.

In ant colony optimization technique, the distance between a node i and master station is calculated as:

$$d\left(i\right) = \sqrt[4]{\frac{P_{M_t} G_{M_t} G_{i_r} h_{M_t}^2 h_{i_r}^2}{P_{i_r} L}} \tag{11}$$

where two ray propagation model is used and P_{Mt}, P_{ir} are the powers, G_{Mt}, G_{ir} are the gains and h_{Mt}, h_{ir} are the heights of the antenna at master station M and i^{th} receiving node respectively.

In fuzzy interference system, the neighborhood nearness calculation by a cluster head is calculated as:

$$N_{nr}\left(i\right) = \frac{1}{N_{tr}}\left(\sum_{j=1}^{j=N_{tr}-1} d\left(i,j\right)\right) \tag{12}$$

where Ntr is number of nodes in the range of transmission, d(i,j) is the distance between nodes i,j.

Based on this, a node becomes cluster head and its send advertisement about its role as cluster head to nodes within the radius called advertisement radius which is calculated as:

$$r_{adv}\left(CH_i\right) = \left[\left\{1 - W\frac{d_{mx} - d\left(CH_i, M\right)}{d_{mx} - d_{mn}}\right\}\left\{\frac{\left(E_{cur}\right)_{CH_i}}{\left(E_{init}\right)_{CH_i}}\right\}\right] r_{adv}^{mx} \tag{13}$$

where r_{adv} is the advertisement radius, d_{mx},d_{mn} are the maximum and minimum distances between the cluster head node CH_i and the master station node M, W is the inequality degree between the clusters in the network, E_{cur} and E_{init} are the current energy and initial energy of the cluster head node.

Relay cluster head is decided based on the condition:

$$P_{r_{xy}}^{i} = \frac{\left[\tau_{xy}\left(t\right)\right]^{\alpha}\left[\eta_{xy}\right]^{\beta}}{\sum_{s \in PR_{CH}\left(s_{x}\right)}\left[\tau_{xs}\left(t\right)\right]^{\alpha}\left[\eta_{xs}\right]^{\beta}} \tag{14}$$

where PR_{CH} is the probable relay set from which cluster head is chosen each time, P^{i}_{rxy} is the probability of r^{th} relay node choosing ant k to move from node x to y. Also τ_{xy} denotes pheromone trail value from node s_x to s_y and η_{xy} denotes heuristic information.

Two-layer codes are used in outer layer to address or resolve the collisions namely LDPC codes and algebraic codes. Joint optimization of these codes and density evolution helps in attaining high throughput in the process. Random access and multi access scenarios are applied on the users and increased the capacity of their error correcting to attain low complexity in the method with a smaller number of transmitters (Macintosh, J. et al., 2023). Semi random access for optimizing the terrestrial satellite network which is IoT oriented helps in optimizing throughput, delay and sum rate values with q learning distributed algorithm and jointly relay selection, access control techniques (Rwandamuriye, F. X. et al., 2023). Hot standby, virtual router and gateway load balancing are three different techniques in first hop redundancy method of routing in which a router failure can be handled using nearby redundant router to take up the responsibility to optimize convergence time, packet loss in the network (Mansour, M. et al., 2022).

A gem in which resource sharing and payment options selection based on their priority levels meeting the deadlines in their jobs is proposed in (Doncel, J. et al., 2014), (Bioglio, V. et al., 2011). Markovian chain is used to compute the response time of each user in the game and thereby analyze the best response dynamics (Durand, S. et al., 2019). Utility functions and centrality using shapley values of nodes play major role in determining cooperation in transportation network (Reese, J. et al., 2006).

Time on task (ToT) algorithm, multi-fruit fly algorithm and gravitational searching algorithm are used to minimize the delay and increase the lifetime of nodes in the network (Raja Basha, A. et al., 2019). Fuzzy logic can handle uncertainties and can help in decision making process even with insufficient information of the network (Singh, M. et al., 2017). Fusion framework dynamic approach for maintaining nodes as active or passive and fixed or varying in time for their behavior is introduced (Tran, D. et al., 2021). Stability is maintained using Lyapunov and matrix inequalities. Consensus algorithms are used to analyze consensus error and stability with respect to each node (Gómez-Gutiérrez, D. et al., 2020). Fixed time and finite time convergences are analyzed.

Node locations are predicted suing temporal and spatial characteristics in the network. Finding optimal path to destination based on location of neighbouring nodes and previous locations of the very own node will help in reducing overhead, improves routing and give rise to a hybrid modelling (Farheen, N. S. et al., 2022). Distance and energy concentrated by bacterial foraging algorithm optimizations, harmony search algorithm which are sub portions in cross layer approach. Further partly informed encoder sparse is used as unsupervised neural network. Selecting cluster head and forming clusters are useful in cutting down energy, computation time, packet loss and lifetime in WSN (Raj, V. P. et al., 2023). Aquila optimizer and election-based optimizer are combined to fulfil multi-objective function in selecting cluster head in the network. They are further incorporated with optimized CNN algorithm which improves precision of clustering and accuracy of the network. Throughput, PDR and network lifetime are better with these multiple optimization techniques working together for WSN (Pandiyaraju, V. et al., 2023).

2.2.1 Inferences From Optimization Techniques for MAC Protocols

- By optimizing the node position using PSO, the PSD for Euclidean distance and autocorrelation are improved with energy efficiency.
- Delay and collisions in a network can be controlled using PSO, ANN and GA optimizations in appropriate MAC parameters.
- Congestion problems can be solved with multi objective functions in heuristic optimization. Priority and energy-based transmissions are included in the objective functions for getting better performance.
- Packet loss, routing overhead and energy consumptions are better with multi objective functions in ant colony optimization (ACO).
- Localization problem in WSN is addressed using ABC optimizations in cluster-based algorithms and least mean square error can be obtained compared to other optimizations.
- Network energy efficiency, lifetime can be improved using cross layer, unequal clusters in ant colony and fuzzy optimizations.
- Throughput and congestions in network are better in data shared by nodes within WSN by using adaptive model cuckoo search algorithm.
- Left out nodes in network and with their remaining energy clusters can be formed using meta heuristic and hybrid optimization related techniques.
- Transceiver optimization gives better lifetime by appropriate next hop selection in DMAC than the cooperative communications applied in clustering protocols.
- Large scale WSN collisions and performance can be improved with integrated MAC in multilevel and backoff algorithms and thresholding to the control frames.
- Gradient optimization algorithm helps in addressing routing, power control and scheduling problems in wireless networks. This gives high SINR, low complexity and energy utility optimizations.
- WSN barrier coverage optimizations can be carried out using ILP, non ILP and OvS models to allow intelligent systems to access the border better and controlling their movement speeds.
- Joint bandwidth optimization for interference between the links and traffic based bandwidth allocation to nodes helps in improving network performance.
- Traffic optimization in FiWi networks makes it worth for 4G.

Table 3 shows different optimization techniques and the issues addressed in them.

2.3 Game Theory Optimization for MAC Protocol

Routing strategy to minimize the cost function of network is given by:

$$F\left(\Pi\right) = \sum_{e \in E} x_e\left(\Pi\right) l_e\left(x_e\left(\Pi\right)\right) \tag{15}$$

where the total traffic e on routing strategy Π is given by:

$$x_e\left(\Pi\right) = \sum_{n \in N} \delta^{e}_{\Pi_n} \gamma_n \tag{16}$$

Here edge $e \in E$, $n \in N$ is the paths available for routing, for any set $\Pi \in E$ we define γ^{e}_{Π} as 1 if $e \in \Pi$ and 0 otherwise.

Table 3. Types of optimization techniques and their addressing issues

Paper	Type of Optimization	Cooperation based	Collision avoidance	Addressed Delay constraints	Throughput	Energy efficiency	Other parameters
(Wang, S et al., 2012)	Distributed MAC	X	X	√	X	X	-
(Jung, L. T. et al., 2011)	Packet size optimization	X	X	X	X	√	Power constraints
(Yan, Z et al., 2019)	PSO	X	X	X	X	√	Node position
(Sun, Z et al., 2019)	Ant colony optimization	√	√	X	X	√	Secure routing
(Saad, E. et al., 2019)	Artificial bee colony	√	X	√	X	X	Mean error
(Singh, K et al., 2018)	Hybrid multi objective	X	√	√	√	X	Congestion control
(Kaur, S. et al., 2018)	Hybrid meta heuristic	X	X	X	X	√	Life time
(Jiang, X. et al., 2019)	Outage probability	√	√	X	X	√	channel statistics
(Asorey-Cacheda, R. et al., 2017)	Non-linear optimization	X	X	X	X	√	Linear programLP
(He, Y. et al., 2018)	Neural network	√	X	X	X	√	Optimal partition
(Gajjar, S. et al., 2015)	Fuzzy and ant colony	X	X	√	X	√	Cross layer
(Narawade, V. et al., 2018)	Adaptive cuckoo	X	√	X	√	X	Optimal rate adjust
(AlSkaif, T. et al., 2015)	Game theory	X	X	√	X	√	Relaying traffic
(Casado-Vara, R. et al., 2018)	Game theory	√	X	X	X	X	False data and quality
(Aravinth, S. S. et al., 2021)	Hybrid swarm intelligence	X	X	√	√	√	Minimum exposure problem
(Singh, S. P et al., 2018)	Genetic algorithm	X	X	√	√	√	LEACH, clustering
(Singh, S. P. et al., 2019)	PSO	√	X	X	X	X	Error variance
(Ramos, D. et al., 2020)	Genetic algorithm	√	X	√	X	X	Stack ensemble
(Singh, S. P. et al., 2018)	Genetic algorithm	X	√	X	√	√	LEACH, clustering
(Lin, Z. et al., 2020)	Cross layer	√	√	X	X	√	Multi input singleoutpt
(Peter, G. et al., 2021)	Hybrid optimization	√	X	√	X	√	Optimal resources
(Robert, V et al., 2021)	Genetic fuzzy	√	√	X	√	X	Channel utilization
(Moura, J. et al., 2019)	Game theory	√	√	X	X	X	Edge computing

A hybrid model for ants/bees to search food is introduced (Saad, E. et al., 2019). Function evaluations and number of iterations are greatly reduced by 20% and 17% respectively. Optimal rate adjustment for a node's share in dealing with congestion is addressed by adaptive cuckoo search (ACS) algorithm (Narawade, V. et al., 2018). Throughput is 90% and delay reduced by 91%, congestion level is 0.19 in this ACS compared to existing conventional methods.

A cross layer approach to address cooperative single output multi-input network is designed taking into considerations the control overhead, control frames and transmitting power (Lin, Z. et al., 2020). It saves 27% energy consumption, hop distance improved by 4.7%. Non cooperative game method with utility function based on contention delay, data rates and priority of vehicles (Amer, H. et al., 2020). It reduces channel busy schedule by 30%, packets loss by 35% and collisions by 37%. An algorithm with fuzzy logic genetic algorithm based on node interferences, channel busy rates and spectrum allocations helps in decision making system in the network (Robert, V. et al., 2021). Channel selection improved by 17% and data transmission improved by 31% and number of secondary users improved by 8% in this approach.

Cuckoo search and lion algorithms are mated to give a better version for addressing attacks and sensitivity analysis in MAC IoT for end-end network performance improvement (Kalyani, G. et al., 2022). Fuzzy logic, wolf optimizations are used with an objective function at the initial state of tree creation itself. It decreases delay in system, conserve the nodes energy and instability period is also controlled (Wang, Z. et al., 2023). Multipath routing, energy optimization during data aggregation, memory and computational power limitations are challenging in a sensor network. These problems are considered in feed forward deep neural network-based buffalo optimization technique which optimizes delay, packet delivery ratio, optimal routing and energy consumption (Rani, S. S. et al., 2023). Higher precision and the mathematical background in calculations by bio inspired optimization techniques like artificial bee colony, genetic algorithm, grey wolf and particle swarm optimizations lead to optimize and process efficiently the near to values which are optimum (Sarkar, T. et al., 2022).

Convolution coding approach followed for WSN with initial bits assigned and later the convolution code is generated for each node (Ahlawat, P. et al., 2022). This generated code is verified with security code to detect the malicious and attacker nodes. ML and DL techniques are used as big data analytics for detection of attackers and cyber security applications (Narayan, V. et al., 2022). Data may be structure or unstructured or imbalance and handles the normal or anomaly data traffic flows by this data analytics. A method with game theory and stochastic petrinets called as SGN (stochastic game net) is proposed to confidentiality, integrity (Kaur, R. et al., 2017). This method detects 80% of the attacks even in 90% malicious nodes are present in the network.

Components of power line communication (PLC) are dominantly the edge power pool, edge layer and latency layer and cloud resilient as backbone. Three real time testbeds are framed to observe path loss using genetic algorithm, PSO and light weight routing protocol with multi-hop technique. Light weight routing protocol is giving optimal multi-path and data transmission in IoT nodes (Okafor, K. C. et al., 2023). Relay selection, power allocation are two methods in which path of packets transmission is identified and nodes selection algorithm is applied to reduce uncertainty, propagation delay and energy consumption. Sending nodes use PSO algorithm, receiving nodes see that multiple pairs communicate with single handshake taking advantage of high propagation delay in underwater networks and in turn reduce delay, power consumption and packet loss and improve throughput (Su, Y. et al., 2020). Cluster head selection and multi-hop using LEACH protocol and cat based salp swarm algorithm with taylor series helps in addressing energy consumption and delay problems. Introducing trust model, integrity factor and data forwarding rates give higher throughput and more number of alive nodes in the network (Vinitha, A. et al., 2022).

In stochastic process, priority to get the resource and job can be applied and deadline can be completed upon user choice. This method of sharing resource deals with game related to more number of users, high traffic and proves that a good performer reaches accurate equilibrium structures.

The fitness function with genetic in PSO is calculated as:

$$\phi\left(z_{1}, z_{2}, \ldots, z_{n-1}\right) = \sum_{i=0}^{n-1}\left(mx_{p_{i},\left(y_{i}, z_{i}\right),\left(y_{i+1}, z_{i+1}\right)} I\left(N\right)\right) d_{i} + mx_{i} d_{i\sum_{i=0}^{p-1} d_{i}} \tag{17}$$

where the individual population members being c=[n,m,z_1,z_2,…..z_{p-1}] and $\sum_{i=0}^{p-1} d_i$ is path length, (y_i,z_i) and (y_{i+1},z_{i+1}) are used in estimating the paths.

Non game theoretical approach is used to improve delay performance, throughput and channel capacity in cognitive radio network even with incomplete information. By applying game theory, the collisions are reduced and thereby the delay in the network also decreases (Dudhedia, M. A. et al., 2022). A novel model with MIMO and OFDMA for 802.11ax is introduced called as Deep-MUX which has 2 components namely channel sounding and resource allocation where both are based on deep learning logic. They reside in access points and doesn't create any calculation efforts for clients. Access points will find out the nearby optimize location, uplink channel will train the downlink channel using deep neural networks (Wang, H. et al., 2023).

Theoretical analysis for optimizing the contention window in MAC protocol is carried out in a global view and adaptive size for the contention window helps for data forwarding wherein the contention window is very small at the near sink area and contention window is larger than required in which the latency is reduced to improve network performance (Li, F. et al., 2021). Power resources in physical layer, frequency resources in MAC layer and routing resources in network layer along with cross layer approach and mean game field can help in handling dense, dynamic distributed nodes to use the resources of centralized distribution to improve transmission rate and decrease delay, overheads (Li, T. et al., 2021). Deep learning reinforcement algorithm MAC protocol helps in dividing a network into blocks with a intention of tuning or controlling few parameters of the network through each block. Blocks are divided based on MAC protocols like 802.11 WLAN, other versions of 802.11 like a/b/g/ac and n (Pasandi, H. B. et al., 2021).

2.3.1 Inferences From Game Theory Approaches for MAC Protocols

- Better probing cost, traffic load and throughput are possible with mean field game on M player system.
- Minimum cost function can be achieved in peer-peer network with minimum steiner problem, its solution compared to nucleus approximations cost function and partition based functions.
- Node connectivity in cooperative games can be measured with shapley values for node centrality.
- Shipping market observe better performance in player benefits with Stackelberg game theory model where as players with aggressive strategy get more benefits in deterrence model.
- Customer, transportation agents help in stabilizing network properties, flow value for multi agent framework with mixed integer programming in Nash equilibrium.
- Nash equilibrium with optimality principle applied for players in WSN is a non-cooperative type of game theory.
- Nash equilibrium with best response is obtained using local poisson and Markov chain maintaining minimum overlap between players.
- Better resource allocation is done with orthogonal FDMA and better fairness index in NASH equilibrium is obtained using appropriate objective function in cross layer approaches.
- Nash equilibrium with fictitious game applied on interference channel give faster convergence rate. Rayleigh, nakagami and racian channels give better performance using this technique.

- Game theory in WBAN with priority-based transmissions for video, data reduces the channel bandwidth requirements and hence give better energy, delay and throughput.
- Game theory and non-linear control algorithm can be used for temperature data quality improvement and false data detection in heterogeneous WSN applications.
- RSU in the place of SDN, BUS for IoV with an evolutionary game concept give better load, throughput.

Figure 1 shows the literature survey carried out in this paper. Table 4 shows the key parameters improved using various approaches.

Figure 1. Literature survey on wireless networks

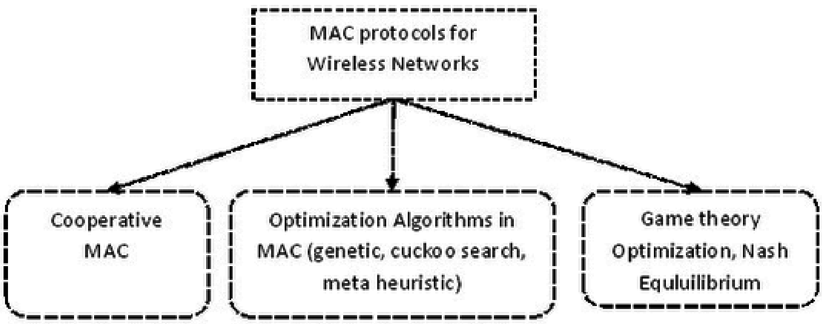

Table 4. Types of algorithms and the key parameters improved

Paper	Type of algorithm	Issues addressed	Parameters increased	Parameters reduced
(Lu, W. et al., 2013)	Sensing and node matrices	Relative error, recovery rate	Attacks detected success rate 98%	Relative error 10%
(Wu, C. M. et al., 2017)	Distributed MAC	Spatial channel reuse, energy	Spatial reuse (3-29)%, throughput 8.9%	-
(Alarifi, A. et al., 2019)	Adaptive Q learning	Residual energy, delay	51% residual energy	41% delay
(Kakhandki,et al., 2018)	Distributed MAC	Transceiver optimization	-	Overhead 32%, decay rate 82%
(Sun, Z. et al., 2018)	ALTA attack localization	Load balance, distance value	98% load balance	15% distance value
(Kaur, R. et al., 2017)	Stochastic game net (SGN)	Attacks, malicious nodes	Handles 90% malicious nodes	Detects 80% attacks
(Nehnouh, C. et al., 2019)	Adaptive and distributed routing	Faults, congestion, latency, traffic	-	Latency 19.4%, faults 0%
(Lin, Z. et al., 2020)	Cooperative cross layer approach	Control overhead, frames, power	27% saving of energy	4.7% hop distance improved
(Amer, H. et al., 2020)	Non cooperative games	Utility functions, channel busy	Channel busy schedule 30%	Packet loss 35%, collisions 37%
(Robert, V. et al., 2021)	Fuzzy logic genetic algorithm	Interference, spect allocation	Channel selection 17%, data 31%	-

3. CONCLUSION

In this paper, we have done a survey on different methods in wireless network to improve its performance. Cooperative communications help in simultaneously accessing channel by multiple nodes and using various traffic models, the distributed MAC can improve network performance in wireless networks. Distributed MAC improves network lifetime by 86%, reduces decay rate by 82% and reduces overhead by 32%. Appropriate objective function in the optimization technique also addresses the congestion, packet loss problems. Optimization reduces congestion level to 0.19, improves throughput by 90% and reduces delay by 91%. Power control, traffic, bandwidth improvements and congestions can be controlled in a network using ABC, PSO, game theory and cuckoo search algorithms. Optimal cuckoo search improves throughput by 90%, reduces delay by 91%. Nash equilibrium in game theory play role for faster convergence of the network. Utility function reduces packet loss by 35%, collisions by 37%.

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CONFLICTS OF INTERESTS

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