Transitive Grouping Based IEEE 802.11AH Protocol for Registration and Data Transmission in Internet of Things

Uchenna Obioma Nwogu

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Transitive Grouping Based IEEE 802.11AH Protocol for Registration and Data Transmission in Internet of Things

NWOGU, Uchenna Obioma[1], ANI, Cosmas Ikechukwu[2]
[1]Department of Electronic and Communications Engineering, University of Nigeria, Nsukka, Nigeria.
[2] Department of Electronic and Communications Engineering, University of Nigeria, Nsukka, Nigeria.
losengineering@yahoo.com

Abstract

Internet of thing (IoT) have improved the lives of humans over these years. There has been an increasing interest of IoT, M2M communication, multi-access wireless schemes, and wireless sensor applications and thus, IEEE 802.11 was amended to IEEE 802.11ah standard which makes use of RAW to reduce contention among the various stations in these networks. The performance of RAW on multi-access wireless network was analyzed by adopting a hybrid system (CSMA-TDMA Environment) that makes use of grouped wireless nodes or stations (IoT devices etc). We identified the problems associated with the increasing growth of subscribers or IoT stations in the adopted architecture. These problems are evaluated through analytical models and optimization algorithms (techniques) and finally, the proposed model is appraised by simulation against the following metrics or problems prevalent in an IoT or WCDMA environment like; congestion at peak time (network delay and registration time delay), resource wastages (channel utilization percentage), throughput and successful transmission probability.

1 Introduction

The IEEE 802.11ah protocol is designed to provide network connectivity to the low power constraint network like Internet of Things (IoTs). IEEE 802.11ah protocol implements channel allocation mechanism called Restricted Access Window (RAW) which splits the channel time into multiple slots. RAW mechanism reduces the packet collisions and also improves energy efficiency. Still, there exists packet collision during channel access in allocated RAW slot. This issue is overwhelmed by Carrier Sense Multiple Access/ Collision Avoidance (CSMA/CA) mechanism which is executed in each group of stations. Time slots of RAW are allocated without consideration of traffic demand that leads to inefficient medium resource utilization. In order to overcome this problem, sequential transmission scheme is suggested which utilizes traffic load for efficient resource utilization. A new RAW mechanism is offered in IEEE 802.11ah standard based IoT network. In this, novel intelligent RAW group adaptation mechanism is introduced which reduces the collisions in data transmission in dense scenarios.

Grouping the stations in IEEE 802.11ah based IoT environment avoids contention and also provides fair channel access to each station. Optimal group formation is difficult in station grouping of IEEE 802.11ah based IoT network. Herein, Traffic Adaptive RAW Optimization Algorithm (TAROA) is used to adapt the RAW parameters in stations grouping. A traffic adaptive RAW parameter optimization algorithm is used for optimum group formation. Here, groups are formed based on the transmission efficiency of the stations. Hidden node problem in IEEE 802.11ah standard is mitigated using hidden node aware grouping scheme. Herein, grouping algorithm is introduced which initially groups and also reconstructs the existing group based on the mitigation scheme. Multi-Objective surrogate modeling is introduced for real time station grouping. Here, surrogate modeling is used to predict the RAW performance for throughput efficiency in IEEE 802.11ah based network.

Registration in AP is significant to transmit sensed data to the AP. Though, reducing registration time is highly challenging task in IEEE 802.11ah based IoT. This problem is resolved using fast centralized authentication which is run by Centralized Authentication Control (CAC) protocol in AP. In this, up and down algorithms are used where three types of modes are present that are waiting, studying and working mode.

2 Aim and Objectives

To overcome inefficient medium resource utilization by sectorizing the service area, utilizing optimization techniques to solve and provide optimal solutions and fair channel access to each station in reduced time.

A. To handle the increasing growth of workstations around a given area (AP)

B. To ensure proper handshake mechanisms this looks at previous threshold of the network and number of stations waiting for association.

C. To reduce contentions among various workstations by ensuring proper scheduling means.

3 Review of related works

Dapeng, et al (2014) introduced several new trends in the development of WLAN technology. Activities and progress in the standardization organization of WLAN, e.g. IEEE 802.11, are introduced. Next generation WLAN technology, a key enabling technology to make WLAN easy to use, together with low power and extended radio coverage are analyzed.

Sergie, et al (2016) in their work titled 'Voice over Wi-Fi: feasibility Analysis Advance in Wireless Optical Communications', investigated the suitability of VoWiFi in satisfying the voice service quality requirements for home and small network users. Three different architectures are investigated based on handoff, load-balancing and repeater. The voice reception quality in terms of jitter, delay and packet loss is monitored for each architecture. It is observed that delay, jitter and packet loss are improved in repeater-based scenario whereas call drop is experienced in both handoff and load balancing scenarios.

The IEEE 802.11ah task group (2000) developed a standard specification for targeting the Internet of Things (IoT) and extended range (ER) applications. The Task Group started the standardization activity in November 2010, and is currently in the last phase of the IEEE ballot procedure. Jain and Sirish (2016) evaluated the performance of IEEE802.11ah protocol through an analytical model using Markov chain model and then evaluated in MATLAB 2013a.

Fabrizo, et al (2011) surveyed the performance issues related to throughput and delay in 802.11 networks and describes proposals to overcome such shortcomings. From the analysis of existing improvements to the IEEE 802.11 standards, from their result, it is clear that there is no single best solution for all deployment scenarios.

Zi and Stefanie (2016) proposed a new criterion, Max-value Enthropy Search (MES) that instead uses the information about the maximum function value. They showed relations of MES to other Bayesian optimization methods, and establish a regret bound. It was observed that MES maintains or improves the good empirical performance of ES/PES, while tremendously lighting the computational burden. In particular, MES is much more robust to the number of samples used for computing the entropy, and hence more efficient for higher dimensional problems. Also, Alvi et al (2015) proposed an adaptive time division multiple access based medium access control (MAC) protocol, called bitmap-assisted shortest job first based MAC (BS-MAC) for hierarchical wireless sensor networks (WSNs). The main contribution of BS-MAC is that: It uses a small size time slots, the number of those time slots is more than the number of member nodes. First two contributions of BS-MAC handle adaptive traffic loads of all members in an efficient manner. The SJF algorithm reduces node's job completion time and to minimize the average packet delay of nodes. The short node address reduces the control overhead and makes the proposed scheme an energy efficient. The simulation results verify that the proposed BS-MAC transmits more data with less delay and energy consumption compared to the existing MAC protocols.

Hadded et al (2015) in their paper titled 'An Adaptive TDMA Slot Assignment Strategy in Vehicular Ad hoc Networks', introduced an Adaptive TDMA Slot Assignment Strategy (ASAS) for VANET based on clustering of vehicles. The main aim of the work is to provide a MAC layer protocol that can reduce inter-cluster interference under different traffic loading conditions without having to use expensive spectrum and complex mechanisms such as CDMA or OFDMA. An analysis and simulation results are presented to evaluate the performance of ASAS. Moreover, the authors compared its performance with two TDMA MAC protocols DMMAC and VeMAC.

Horton and Leutenegger (1994) presented a new iterative algorithm, the multi-level algorithm, for the numerical solution of steady state Markov chains. The method utilizes a set of recursively coarsened representations of the original system to achieve accelerated convergence. It is motivated by multi grid methods which are widely used for fast solution of partial differential equations. Initial results of numerical experiments are reported, showing significant reductions in computation time, often an order of magnitude or more, relative to the Gauss-Seidel and optimal SOR algorithms for a variety of test problems. It is shown how the well-known iterative aggregation-disaggregation algorithm of Takahashi can be interpreted as a special case of the new method.

Imgar (2011) provided a tutorial on key issues in hidden Markov modeling in his paper titled "Seven things to remember about hidden Markov models: A tutorial on Markovian models for time series". Hidden Markov models have become very popular models for time series and longitudinal data in recent years due to a combination of (relative) simplicity and flexibility in adapting the model to novel situations. The tutorial covers the conceptual description of the model, estimation of parameters through maximum likelihood, and ends with an application to real data illustrating the possibilities.

Danilo (2017) in his own paper titled **"**Using Hidden Markov Models to Model Life Course Trajectories" provided an introduction on Hidden Markov models (HMM) for longitudinal data analysis in population and life course studies. In the Markovian perspective, life trajectories are considered as the result of a stochastic process in which the probability of occurrence of a particular state or event depends on the sequence of states observed so far. In other words, considering life trajectories as sequences of mutually exclusive states (e.g., sequences of employment statuses), a Markovian process focuses on successive transitions and attempts to depict the life history of an individual looking at the probabilities to switch to the different states of interest given the state history lived so far. Starting from the traditional formulation of a first-order discrete-time Markov chain (first-order transitional model), we present and discuss the relevance of Hidden Markov models for population studies using longitudinal data on self-reported health condition from the Swiss Household Panel study.

Tamas, et al (2014) presented a research of Markov chain based modeling possibilities of electronic repair processes provided by electronics manufacturing service (EMS) companies. These stochastic processes are considered as business-like, industrialized activities that are typically complex with a high number of process states and many possible paths from the start state to the absorbing end states. Two models based on absorbing and acyclic absorbing Markov chains are introduced in order to model these processes. The presented method provides a quick tool for determining the most important operational and statistical parameters of the process and mapping the paths that contribute the most to the total load of the process. These results support several managerial applications concerning e.g. process improvement, quality control and resource allocation. The proposed model is illustrated with an industrial application.

Mohammed, et al (2008) presented a new technique for Bandwidth allocation among users in a server controlled network in a technical, industrial or institutional setup. In creating the project they used fair queuing i.e. the system which is connected to the internet and on which our software is installed will be receiving all the packets requested from the user. Then putting all packets in a queue and transmitting them after a suitable delay will guarantee that the users receive the allocated bandwidth. The method is to send all network traffic to a centralized bandwidth manager that provides prioritization, rate limiting and other related services.

Miriyala (2019) proposed a RAW based Novel Service Differentiation Scheme for Group-Synchronized DCF. In this, Group Synchronized Distributed Co-ordinated Function (GS-DCF) implements novel RAW mechanism which splits the channel time into various time slots. Here, RAW slots are allocated based on the service requirement of the stations with minimal additional overhead. Proposed method assigns priorities to the stat ions based on their throughput requirement. In their work titled "Range Extension in IEEE 802.11ah Systems through Relaying**",** Enis et al (2017) proposed a range extension method in IEEE 802.11ah systems with the usage of relaying system. Herein, Decode and Forward strategy is used in communication between AP and end stations. The proposed strategy is implemented in relay station in order to extend the range in IEEE 802.11ah systems. In this, robust modulation and coding schemes are used to derive results on available ranges.

Miriyala and Harigovidan (2017) proposed throughput and energy efficiency analysis of IEEE 802.11ah RAW mechanism. RAW reduces the contention among different stations with the usages of splitting up of stations into several groups. In this, performance of the RAW mechanism is analyzed through different Modulation and Coding Scheme (MCS). Performance evaluation of the RAW is implemented in draft standard. Also, Justin and Nithya (2018) proposed a mathematical and simulation analysis of contention based resolution mechanism for IEE 802.11ah standard based IoT network. In this, Binary Exponential Backoff (BEB) mechanism is used to resolve the contention among stations inside the RAW group. Here, new contention window is calculated using the efficient BO algorithm without any complex computations and additional control overhead.

Sangeetha and babu (2019) in their work titled "Performance analysis of IEEE 802.11ah wireless local area network under the restricted access window-based mechanism" proposed performance analysis of IEEE 802.11ah standard in wireless local area network under RAW mechanism. Contention during channel access issue is overwhelmed by Carrier Sense Multiple Access/ Collision Avoidance (CSMA/CA) mechanism which are utilized in each group of stations. In this, Discrete Time Markov Chain (DTMC) algorithm is used to know the state of each station.

Xiaoying and Seoung (2017) proposed performance improvement of sub 1 GHz WLANs for IoT environment. Time slots of RAW are allocated without consideration of traffic demand that leads to degrade the medium resource utilization of each station. In order to overcome this problem, sequential transmission scheme is proposed in this paper which utilizes traffic load for efficient resource utilization.

Pranesh and Jae-young (2017) in their paper; Performance Improvement of Sub 1 GHz WLANs for Future IoT Environments, proposed station grouping with the minimum association delay in IEEE 802.11ah based IoT network. This paper initially performs authentication/association scheme in IEEE 802.11ah standard. Accordingly, analytical model is introduced to estimate the best group size. The proposed analytical model estimates the analytical model with the less association delay in the network.

Tian, et al (2017) proposed the real time station grouping under dynamic traffic for IEEE 802.11ah network. Herein, Traffic Adaptive RAW Optimization Algorithm (TAROA) is used to adapt the RAW parameters in stations grouping. A traffic adaptive RAW parameter optimization algorithm is used for optimum group formation. Here, groups are formed based on the transmission efficiency of the stations.

Victor et al (2016) in their paper titled "IEEE 802.11ah: A Technology to Face the IoT Challenge" proposed IEEE 802.11ah technology to face the IoT environment challenges. IEEE 802.11ah technology is extended version of the WiFi amendment which supports IoT environment. This paper provides brief overview of the IEEE 802.11ah technology working in the IoT environment. IEEE 802.11ah standard overcomes the problems that are present in current IoT network such as power constraints and coverage.

Tian, et al (2016) proposed the implementation and validation of IEEE 802.11ah module in the NS3 simulator. This paper introduces two backoff states for each station during data transmission. Here, Enhanced Distributed Channel Access (EDCA) mechanism is used to manage the transmission inside the slotting range. First backoff state is performed outside of the RAW slot and Second backoff state is performed inside of the RAW slot.

Bankov, et al (2017) in their paper titled "Fast Centralized Authentication in Wi-Fi Halow Networks" proposed fast centralized authentication in WiFi Halow network (IEEE 802.11ah). Registration delay problem is resolved using fast centralized authentication which is run by Centralized Authentication Control (CAC) protocol in AP. And it also reduces the contention among stations during registration process, since group of station request registration simultaneously.

Damayanti, et al (2016) in their paper titled "Collision chain mitigation and hidden device-aware grouping in large-scale IEEE 802.11ah networks" proposed the collision chain mitigation and hidden device-aware grouping in large-scale IEEE 802.11ah networks. Hidden node problem in IEEE 802.11ah standard is mitigated by proposed hidden node aware grouping scheme. In this, grouping algorithm is introduced which initially performs grouping and also reconstructs the existing group based on the mitigation scheme.

Tian, et al (2019) proposed multi objective surrogate modeling technique for real time station grouping in IEEE 802.11ah standard. In this, surrogate modeling is used to estimate the RAW performance in order to measure throughput efficiency. Model based RAW Optimization Algorithm (MoROA) is proposed for effective station grouping which considers the stations throughput. Yoon, et al (2016) proposed regrouping algorithm in order to alleviate the hidden node problem in IEEE 802.11ah networks. This paper addresses the group based contention mitigation problem regarding to enhance the performance of the proposed system. Here, Hidden Matrix based Regrouping (HMR) algorithm is used to group the station effectually with the aid of finding hidden nodes.

Tian, et al (2016) proposed the evaluation of the IEEE 802.11ah standard with RAW mechanism in dense IoT scenario. Proposed method initially divides the network into multiple groups based on the grouping strategy. In this, RAW group is formed with consideration of succeeding parameters such as traffic load, number of stations and RAW group. And also optimize RAW parameters to group the stations.

Nurzaman, et al (2018) proposed IEEE 802.11ah based scalable network architecture for Internet of Things (IoTs). In order to overcome the constant RAW size allocation problem this paper proposes RAW size adjustment scheme. Here, RAW size is adjusted based on the traffic load of the stations (sensor nodes). Herein, Relay Access Point (RAP) is used as communication interface between stations and Access Point (AP). AP coverage is divided into different groups based on the available channels. AP provides TDMA slots to the RAP to transmit their data to the AP node.

Hanifa et al (2019) in their paper titled "AID-based backoff for throughput enhancement in 802.11ah networks" proposed Association ID (AID) based backoff for IoT networks with throughput enhancement in 802.11ah standard. Hidden node problem is overwhelmed in this work by performing sectorization and grouping. Here, AP divides its coverage range into six equal non-overlapping sectors. It forms groups using modified Welsh Powell algorithm. Stations are grouped based on the distance and their received power value. After completion of grouping, AP allocates slots to each group based on their sector interval. Here, backoff timer is provided to each stations based on their AID in ascending order.

Tung-Chun, et al (2019) proposed a traffic aware sensor grouping for IEEE 802.11ah with IoT network. In this, channel utilization is improved through traffic aware grouping and regression based channel success probability analysis. Herein, greedy algorithm is used to group the sensor based on the channel utilization. Initially, greedy algorithm forms empty sensor set and also set channel utilization for each group as zero. If sensor node exists with high channel utilization, then it assigns into group. This process continues until all sensor node assigned into the group. Regression model is used to measure the contention success probability of the group.

Nurullah et al (2018) proposed a Hybrid Slotted CSMA/CA and TDMA (HSCT) for efficient massive registration for IoT devices. Time required for registration is minimized through Centralized Authentication Control (CAC) method based authentication and association. Proposed HSCT uses Carrier Sense Medium Access (CSMA)/ Carrier Avoidance (CA) algorithm to send authentication request to the Access Point (AP). Time Division Medium Access (TDMA) algorithm is used to send association request to the access point and also send response for both authentication and association request.

Zulfiker, et al (2019) in their paper titled "Performance Evaluation of Heterogeneous IoT Nodes with Differentiated QoS in IEEE 802.11ah RAW Mechanism" proposed a heterogeneous IoT nodes with differentiated QoS in IEEE 802.11ah RAW mechanism. Proposed heterogeneous network comprises of both QoS and Non-QoS nodes that are transmit QoS and Non-QoS traffic. This work concentrates on three types of traffics that are Best Effort, Video and Voice. Herein, Markov chain model is used to predict the queue state of the buffer. Backoff time of the Non QoS node is higher than the QoS node to transmit data in RAW slot. Waiting time of the station is mitigated through open contention window where stations are transmitted their data to the AP.

4 Methodology

In our work, we address problems that are present in the adopted IEEE 802.11ah based IoT model. Our network comprises of three nodes that are Access Point (AP), Relay AP (RAP) and Stations (sensor nodes).

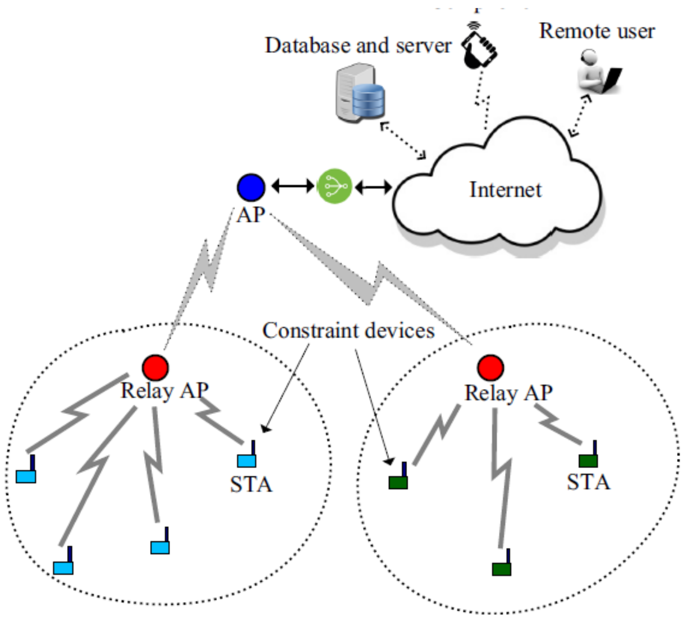

Fig. 1 Architecture for AP and RAP communication

4.1 Adopted Technology

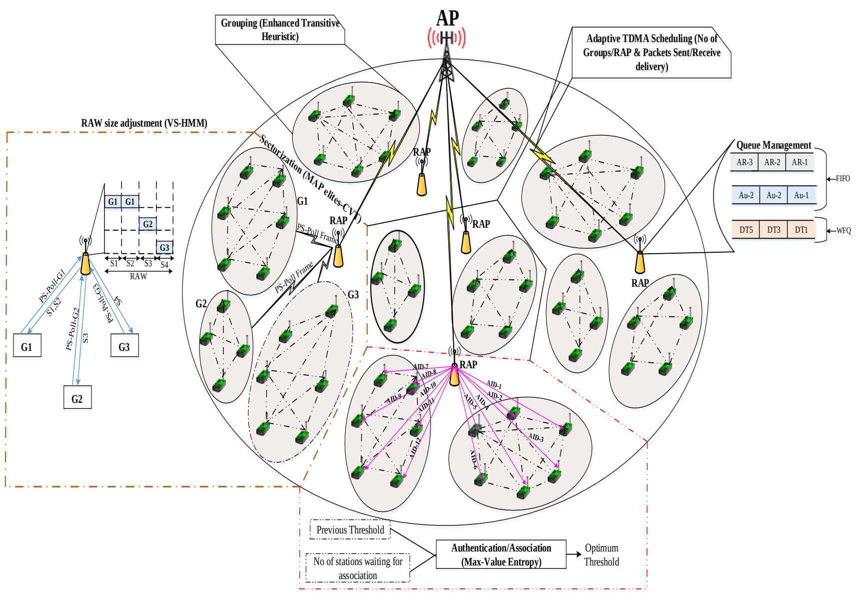

Fig. 2 Hybrid slotted CSMA-TDMA Network

- Existence of packet collision during channel access but overcame with CSMA/CA

- RAW slots allocated without considering traffic demand, that leads to inefficient medium resource utilization
- Optimal group formation is difficult. (TAROA) is used to solve and adapt RAW parameters in stations grouping)
- Hidden Node problems still exists: solved using hidden node aware grouping scheme)
- Doesn't provide an optimal solution and it consumes more time to find optimal solution.
- Registration time reduction is challenging
- It uses Markov chain and M/G/Z model based slot allocation mechanism which increases the mathematical computations with complex procedures.
- Markov Chain based queue state prediction takes more time and also provide exact state of the stations. Contention is more here without proper scheduling

5 Identified Research Gap

RAW size adjustment in IEEE 802.11ah based scalable network architecture is adopted for IoT environment (Miriyala et al., 2017). Here, TDMA slot is allocated to the RAP that may lead to contention due to same channel allocation for two different RAP. Furthermore, Overlapping is high in stations grouping due to available channel based group formation. AID based back-off timer is estimated for throughput enhancement in IEEE 802.11ah network (Justin and Nithya, 2018). More effects are required under sectorization, since it plays vital role in reducing interference among different stations and hidden node problem. Here, traffic demand of station is significant metric in group formation in order to enhance channel utilization. Traffic demand based stations grouping is introduced in IEEE 802.11ah standard based IoT network (Sangeetha and Babu, 2019). In this, Greedy based grouping doesn't provide an optimal solution and also consumes more time to find optimum solution. Because, it's searching behaviour is not effective and choosing the choice from the current state. Efficient massive IoT device registration is performed using hybrid slotted CSMA/CA and TDMA algorithm (Xiaoying and Seung, 2017). More analysis is required in parameters setting of threshold estimation in order to provide effective authentication/association process to the stations. Here, authentication and association request process runs with the usage of both traditional CSMA/CA and TDMA algorithms that increases the mathematical computations with complex procedures (Authentication/Association (Req/Res)). Markov chain and M/G/1 model based RAW slot allocation mechanism is introduced in IEEE 802.11ah networks (Pranesh and Jae, 2017). Markov chain based queue state prediction takes more time and also doesn't provide exact state of the stations. Contention is more, since part of the beacon interval is kept open where all stations transmit their data without proper scheduling.

6 Defining the Research Gaps

6.1 CVT-ME Based Sectorization

Here, we sectorize using CentroidalVoronoi Tessellation (CVT)-MAP Elites (CVT-ME). In this, network is sectorize based on the location of RAP which is considered as centroid in CVT algorithm. Proposed CVT-MAP Elites, first execute CVT to generate Voronoi after that MAP-Elites is executed. Sectorization in our network reduces hidden node problem drastically and also avoids medium contention.

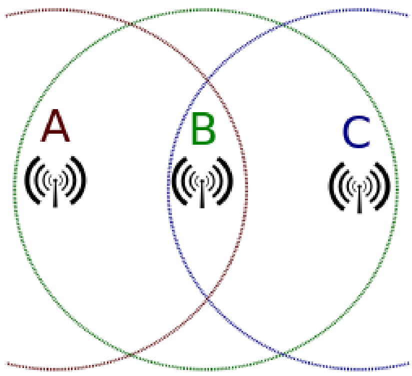

Fig. 3 Architecture for Hidden node problem

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6.2 Transitive Grouping

Grouping is necessary to improve channel utilization of the stations and also reduces contention overheads. Our work utilizes the Enhanced Transitive Heuristic (ETH) algorithm to group the stations where Condorcet's criterion is used. Here, three metrics are used to group the stations that are distance, SINR and Traffic demand. Proposed ETH algorithm doesn't require prior knowledge of number of clusters and also provides higher accuracy in grouping.

6.3 Max Value Registration

Registration is performed before going to transmit sensed data to the AP. Here, four ways handshake mechanism is established that are Authentication Request/Response and Association Request/Response. Our work estimates optimum Authentication Control Threshold (ACT) via implementing Max Value Entropy function. In this, two metrics are considered that are previous threshold and number of stations waiting for association.

6.4 Adaptive Raw Slot Allocation Mechanism

We propose Adaptive Time Division Multiple Access (TDMA) algorithm to allocate slots to the RAP in order to communicate with AP. AP transmits RAW to each RAP during their respective slots. Proposed Adaptive TDMA, adaptively changes slots for each RAP based on number of groups per RAP and Packet Sent/Receive Delivery metrics. Here, AP sends RAW to the RAP to allocate slots to group of stations. After receiving RAW from the AP, RAP adjusts its slot based on the state of the group. For which, we propose Variable Size-Hidden Markov Model (VS-HMM) to estimate the state of each group where two metrics are taken to into account that are Traffic load and collision rate. This way of allocating slot reduces contention between stations and also improves throughput in data transmission.

6.5 Queue Management

Our work manages queue in each RAP based on the dual algorithms that are First in First out (FIFO) and Weighted Fair Queuing (WFQ) techniques. RAP contains three queues that are Authentication, Association and Data Transmission. Here, Authentication and Association queues are managed using FIFO algorithm. And, data transmission queue is managed through WFQ algorithm where three metrics are considered Arrival Time, Packet Size and Expected Delay. This way of managing queue is used to perform different process like authentication/association and data transmission effectually.

7. Conclusion

The optimization techniques deployed to improve the performance of IEEE 802.11ah Internet of Things also fits them in for high rate broadband access of any multi-access network, no matter how sophisticated it is. This takes care also of recent evolving standards (WCDMA, 4G cellular) where M2M Communication, wireless sensor applications and broadband access is used. Mathematical analysis/models and graphical simulators will be used to evaluate the proposed solutions/models against the aforementioned indices to show the anticipated improvement in service delivery.

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