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Development of Game Theory Strategy for Estimating Mobility Variety in Approaching Wireless Networks

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Abstract

Game theory designed with a set of structured tools with an evaluation tool for the tedious interaction among logical players. This theory approaches for analyzing of communication networks, which functions with autonomous structured networks and the designed network devices can take rational decisions according to network congestion. The proposed structure consists of mixture frame for channel allocation for random probability for accessing channel. The main objective of this work is to reduce the cost of wireless access while satisfying the quality-of-service requirements thereby developing a game theoretic model and also to estimate both the stable coalitional structure and the optimal channel access policy from the game model. Then the average cost of optimal and stable coalitional structure is compared with the dominant coalitional structures which achieves the lowest average cost.

Keywords: Game theory, channel allocation, Quality of Service, Network congestion, Wireless access.

INTRODUCTION

In the recent years, there is a rapid growth in the evolution of wireless communications industry which can be sustainably achieve high quality data rate between the compact devices [1], [2]. Wireless data transmission system have the characteristics to conflict transmission and losses effects uncertainty compared to the wired systems [3]. These beneficial features grasp the occupancy of the media and the public interest. Cellular networks have a rapid growth in the earlier decades and covers the users worldwide [4]. The quality-of-service (QoS) performance and the cost of wireless access are important factors which will affect the provisioning of emerging mobile applications and services [5]. Channel reservation approach is adopted for set of mobile groups was proposed in the wireless access system [6]. Game theory model identifies the mobility variation of mobile users in a view to minimizing the cost reduction [7]. Quality of services is achieved by the channel allocation methodology in wireless networks.[8]. The acceptable guaranteed QoS is attained by request probability based on the mobility index and channel congestion [9]. Game theory can be broadly classified in to cooperative and non-cooperative. Competing players interactions are handled by the Non cooperative theory, where individual player identifies structured separately for improvement of its performance or loss reduction.[10], [11].

Several procedures available like Nash equilibrium for deriving non cooperative games. Many applications concentration in early novel approaches involves congestion control, spectrum sharing, power control, resource allocation [12]. Whereas in the non-cooperative strategy verifies competitive structure,

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and also cooperative game theory approaches analytically for rational player study when cooperate [13]. Cooperative games involves the structured formation of group allocation of such players, that strengthen the particular player position in the game.[14]. Coalitional game theory deploys the cooperative behavior. the key structure formation is to make a cooperative collection of groups [15], By the cooperating formation the players in the group can able to strengthen their position and improve their resource allocation and their utilities [16].

A coalitional game was formulated for data routing or forwarding among multiple nodes. To share the benefit of data forwarding in a fair manner, Shapley value was applied. A coalitional game model is used to obtain the group of trustful and reliable nodes to transfer data in adhoc/sensor networks. The Gale-Shapley deferred acceptance algorithm (DAA) was applied for coalition formation to maximize coalition throughput [17], [18]. In the proposed method we use coalitional game theory to study the cooperative behavior of mobile nodes for distributed wireless access under QoS constraints.

Stochastic Structured Game Theory

In stochastic game more than one player are involved in dynamic game. The game is strategy involves structured stages sequentially. While at the starting stage the game is in random state, the players identify the role and action and chooses the payload based on the current state and chosen actions.[19].

The game proceeds in a way of choosing to a random state whose allocation depends on the early before state and actions. And the continual process is occurred. Markov decision processes (MDPs) [20], is structured by an mathematical design modelling for decision- making in various situations. MDPs are very useful in understanding a broad range of optimization solutions.

Stochastic Game Theory General Applications

Generally, in vehicular telematics, to transfer the data collected from on-vehicle sensors to the server, channel access to the roadside base stations may need to be reserved. Similarly, in a mobile social networking application, mobile users can update their activity on the social network server using reserved channels for wireless access to the base station. For these applications, QoS performance in terms of packet loss and packet waiting time has to be maintained below the target thresholds while minimizing the cost of channel reservation and access.

A wireless channel can be proactively reserved by a mobile user from a set of base stations owned by the same network operator [21]. When a mobile node is no longer in the coverage area of a base station, the reserved channel will be underutilized. Therefore, to improve channel utilization, multiple mobile nodes with different mobility can share the channel reservation so that the cost of wireless access for each mobile node will be reduced [22]. Multiple mobile nodes can form a group or coalition to share the reserved channel. When the mobile nodes in the same coalition are at different locations, each of the mobile nodes can fully access the reserved channel. But, if more than one mobile node from the same coalition is at the same location, collision can occur. Therefore, a coordination mechanism would be required for channel access for the mobile nodes in the same coalition [23], [24].

In the proposed model, to study the mobile node behavior random point structure is identified. The algorithm is random allocation-based mobility management schemes for wireless communication patterned structure systems. This model identifies the movement pattern structure of mobile users, and pinging their location, speed and fitness acceleration variation over time. Mobility models are considered for analyzing in the evaluation of new network protocols. The movement of random variation of mobile nodes don't have any restrictions even the direction and speed are allocated independently of other nodes. The mobility model movement might distinguish the genetics of the network node in the given module. A particular node chooses a random destination point and moves at a constant velocity to that particular point, after the threat alert it waits and standby for certain time, it allocates and new destination is chosen and different new speed it moves to the destination and so on.

The epoch is otherwise called as movement of a node from source to its next end place is referred. The destination points (waypoints) are uniformly randomly chosen in the system area.

Channel allocation sharing approach is designated for the set of mobile users, the aim of the proposed approach is to minimize the cost of wireless access in mobile diversity. In the designed game model Quality-of-Service (QoS) is achieved by controlling the packet losses and packet waiting time. The proposed model classified in to two categories in such a way coalitional game and stochastic game for channel reservation and channel access respectively. Through which stable results are possible.

Again, the stable and optimal structure is compared with the dominant strategy under non-cooperative game theory.

This paper discuss introduction in the first chapter, further the paper proceeds as follows, chapter II discusses the wireless Access-joint reservation and channel access, the third chapter discussed optimal channel access- the stochastic game model and the fourth chapter discusses system model and assumptions and finally chapter six and seven discusses the results and conclusion.

WIRELESS ACCESS- JOINT CHANNEL RESERVATION AND CHANNEL ACCESS

For sharing the reserved channel, groups or coalitions of mobile nodes are formed using coalitional game theory, while the channel access policy is obtained from a stochastic game. The upper game is the coalitional game for optimal channel reservation, while the lower game is the stochastic game for optimal channel access. The decisions of the mobile nodes obtained from the coalitional game (to form coalitions) are based on the solution of the stochastic game.

Again, the decisions of the mobile nodes obtained from the stochastic game (to access wireless channel) are based on the results of coalitional game (i.e., coalitional structure). To facilitate the formation of coalitions among mobile nodes for channel reservation, a coordinator is assumed to exist (e.g., vehicular telematics server or mobile social network server). The coordinator maintains a list of active mobile nodes which are available for coalition formation. While the coordinator provides information necessary for coalition formation among the mobile nodes, it does not control the decision of the individual mobile nodes. That is, the mobile nodes can decide to form coalitions independently in a distributed manner. The hierarchical structure of channel reservation and channel access is shown in Figure 1.

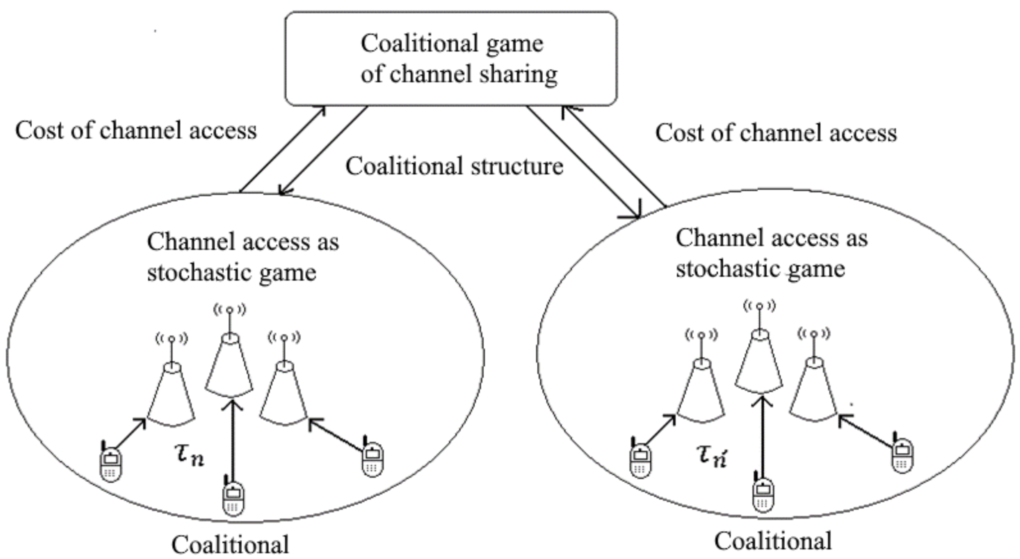

Figure 1. Channel reservation and channel access of a mobile node.

Optimal Channel Reservation- The Coalitional Game Model

A rational coalition formation scheme is considered where each mobile node is rational to minimize its individual cost given the decisions of other nodes. The game model for coalition formation can be formulated as follows,

1. The players are the mobile nodes with the set of all mobile nodes denoted by N= {1….n}. A coalition of nodes is represented as S⊆N. and it is mentioned as grand coalition.
2. The idea of individual node is to split and join for any coalition.
3. The impact of the payload is a collective of players forming a coalition, the coalition state identifies the player upon the estimate of the payment will be shared among the members.
4. It is also defined as the cost which is composed of the channel access cost $C_{ac,n}$ which is given by

$$\overline{C_{ac,n}} = \sum_{S_{n},\psi_{n}\in\Delta_{n\times\psi}} \varsigma\,(S_n,\psi_n,\pi^*)\pi_n^*(\psi_n \backslash S_n)q_n^{\pi}(S_n) \quad (1)$$

where $\overline{C_{ac,n}}$ is the channel access cost. (S_n) is the packet loss rate ψ_n is the action space Δ_n is the finite local state space ψ is stationary cost. $\varsigma(S_n,\psi_n,\pi^*)$ is the immediate cost, immediate loss, immediate waiting time functions. π_n^* is the best response $q_n^{\pi}(S_n)$ is the stationary probability of a mobile node Therefore, the negative payoff of mobile node n is defined as follows

$$\varsigma_n = \overline{C_{ac,n}}\left(S^{(n)}\right) + \frac{\sum_{l\in L}\wp l}{|S^{(n)}|} \quad (2)$$

where $\left(S^{(n)}\right)$ is the coalition which mobile node n belongs. In this case, the channel access cost $\overline{C_{ac,n}}\left(S^{(n)}\right)$ is defined as a function of coalition$S^{(n)}$. ς_n is the negative payoff of the mobile node. l is the location of the mobile node. $\wp$ is the payoff vector. This channel access cost is obtained given that the constrained Nash equilibrium policy for channel access is applied. A coalitional structure is a group of coalitions that lasts all the mobile nodes in N and is defined as ω= {S1….Sj...S_J}, where J is the total number of coalitions are partition ω. The total number of possible coalitional structures for N mobile nodes is given by

$$D_i = \sum_{j=0}^{i-1}\binom{i-1}{j}D_j \quad (3)$$

where D_i and D_j is the Bell number.

The coalitional structure number increases gradually in an exponential way depends on the mobile node numbers. The approximation and reduction method for coalitional structure can be applied to solve the complexity problem. The proposed model is formulated as a Non-Transferable Utility (NTU) coalitional game (N, V), where N is the set of players and V is a mapping such that for every coalition $\mathcal{S}$ ∈ N, $V(\mathcal{S})$ is a closed convex subset that contains the payoff vectors achievable by players in $\mathcal{S}$. In this game, the negative payoff is a function of channel access and channel reservation costs. These costs are not allowed to be arbitrarily apportioned among the mobile nodes in a coalition, since the individual payoff is restricted. In such case of rational coalition formation, the expected result is the coalitional structure, ω, which can exhibit the following internal and external stability notions

Internal Stability

A coalition S ∈ ω is internally stable if no mobile node can reduce its cost by leaving its original coalition and acting alone, i.e., ζn(S) < ζ_n ({n})

Where, ζn(S) is the cost achievable by a player in coalition S. ζ_n ({n}) is the cost achievable by a player in a partition ω of a mobile node *n*.

External Stability

A coalition S ∈ ω is externally stable if at least one player does not benefit from the merger of R and S. Mobile nodes agree to split into multiple coalitions if the cost of all mobile nodes in the new coalitions is smaller than that in the current single coalition.

Partitioning

Given the original coalition Sj, mobile nodes in this coalition can be partitioned into multiple new coalitions, whose set is denoted by M^+, if the channel access probability is denoted by,

$$\tau_{l,n} = \sum_{S_{b,n=0}}^{B} \sum_{S_{h,n=1}}^{H} \sum_{\psi_{n\in\Delta_n}}^{H} \psi_n \, \pi_n^*(\psi_n \backslash S_{b,n,l}, S_{h,n}) q_n^\pi(S_{b,n,l}, S_{h,n})) \quad (4)$$

Where, $\tau_{l,n}$ is the channel access probability. B is the largest queue size. H is the maximum number of phases. $S_{b,n,l}$ is the number of packets in the queue in the location l. $S_{h,n}$ is the phase of packet arrival. ψ_n is the action space. $q_n^\pi(S_n)$ is the stationary probability.

Mobile nodes agree to split into multiple coalitions if the cost of all mobile nodes in the new coalitions is smaller than that in the current single coalition.

Merging

The stable coalitional structure is obtained by, discrete-time Markov chain can be formulated as dynamic coalition formation. The state space is as follows

$$\Omega = \{(\omega_x): x = \{1, \ldots, D_N\}\} \quad (5)$$

Where, Ω is the state space. ω_x represents a coalitional structure and D_N is the Bell Number and can be obtained from equation (3). The transition probability matrix of this Markov chain is denoted by Q whose elements $Q_{\omega,\omega'}$ represents the probability that the coalitional structure (i.e., state) of all mobile nodes changes from ω to ω'. This transition probability is as follows

$$Q_{\omega,\omega'} = \begin{cases} \prod n\epsilon v_{\omega,\omega'} \left(\delta\beta_n(\omega'|\omega)\right) & \omega > \omega' \\ 0 & Otherwise \end{cases} \quad (6)$$

Where, $\omega>\omega'$ is a feasibility condition. $Q_{\omega,\omega'}$ represents the probability that the coalitional structure (i.e., state) of all mobile nodes changes from ω to ω'. $V_{\omega,\omega'}$ denote the set of candidate mobile nodes which are involved in the coalition formation decision such that the coalitional structure changes ω to ω'.

In particular scenario, if the coalitional structure ω' is reachable from ω given the decision of all mobile nodes, then the condition $\omega > \omega'$ is true. otherwise, it is false. δ is the probability that a mobile node decides to execute the decision on changing the coalition. $(\omega'|\omega)$ is the best-reply rule of mobile node n. This structured identified rule is as

$$\beta_n = \begin{cases} \hat{\beta}, & S_n > S_n^{max} \\ 0, & W_n > W_n^{max} \\ \epsilon, & otherwise \end{cases} \quad (7)$$

Where, $0 < \beta \leq 1$ is a constant, ϵ is a small that corresponds to the probability that a mobile node makes an irrational decision, $\epsilon = 10^{-3}$, and $\beta >> \epsilon$. Mobile node n switch the coalition if the QoS requirements in terms of maximum packet loss S_n^{max} and waiting time W_n^{max} are not satisfied. Further, a mobile node can make an irrational coalition formation decision due to either, (i) lack of information, (ii) need for exploration in the learning process. The average individual cost of mobile node n can be obtained from

$$\overline{C_n} = \sum_{x=1}^{D_N} \theta_{\omega_x} \tag{8}$$

Where, $\overline{C_n}$ is the average individual total cost. θ_{ω_x} is the probability that the coalitional structure ω_x will be formed. D_N is the Dell number. In this regard, singleton ergodic sets are referred to as the absorbing states. Specifically, $\omega \in \Omega$ is absorbing, if $Q\omega$, $\omega' = 1$.

The concept of an ergodic set is important for the coalition formation process. Once all mobile nodes reach the state (i.e., Coalitional structure) in an ergodic set, they will remain in this ergodic set forever. In addition, the mobile nodes will stop evolving once the absorbing state is reached. The absorbing state is referred to as the stable coalitional structure ω^*. In particular, no mobile node has an incentive to change its decision given the prevailing structure.

Distributed Algorithm of Coalition Formation

1. The mobile nodes are partitioned into {$\mathcal{S}1(t)$, . . . , $\mathcal{S}s(t)$ for $\mathcal{S}j$= N.
2. Mobile node n observes the performance measures Sn and Wn, and the channel access cost $C_{ac,n}$ given its current coalition.
3. Compute cost ζn.
4. Update the knowledge of the cost.

This algorithm is based on reinforcement learning in which the mobile nodes gradually learn the cost of wireless access for different coalition formations. The decision is made by each mobile node based on the knowledge $k_n(\cdot)$ to minimize its cost. Note that $0 \leq$ rnd ( ) ≤ 1 is a random number generator function. For channel access, a mobile node has to use the best response policy $\pi n^*(\psi n|sn)$, which can be obtained by using a low-complexity value iteration algorithm. Note that the mobile node can observe the channel access probability $\tau_{l,n}$ of the other mobile nodes locally.

OPTIMAL CHANNEL ACCESS- THE STOCHASTIC GAME MODEL

A stochastic game model with independent state information is formulated to obtain the channel access policy (i.e., constrained Nash equilibrium) which minimizes the cost due to the channel access of each mobile node while satisfying the QoS requirements of data transmission from each mobile node to base station. The strategy of each player is the channel access policy which minimizes the cost of wireless channel access.

State Space and Action Space

Player (i.e., mobile node) n in the proposed stochastic game is defined by {Δ_n, ψ_n,$\mathbf{P}_n(\psi_n)$,Φ_n}, where Δ_n is a finite local state space, and ψ_n is the action space, which we assume to be identical for all mobile nodes, i.e., $\psi_n = \psi$. $\mathbf{P}(\psi_n)$ is the state transition probability matrix given action $\psi_n \in \psi$, and Φ_n is a set of stationary cost and performance measures to be optimized and/or constrained.

$$\Delta_n = \{(B, L, H)\} \tag{9}$$

Where, Δ_n is the local state space. B is the no. of packets in the queue of mobile node, L denotes location of the mobile node, and H is the packet arrival rate. Let $\Delta_{\mathcal{S}} = \Delta_1 \times \cdots \times \Delta_n \times \cdots \times \Delta_{|\mathcal{S}|}$ denote the global state space where × is the Cartesian product. The action space of mobile node n is defined as ψ= {0, 1} where actions $\psi_n = 1$ and $\psi_n = 0$ correspond, respectively, to the cases where mobile node n accesses and does not access the reserved channel. Assume that the state (i.e., the location of the mobile node and the number of packets in its transmission queue) is observed at the end of every time slot.

At the beginning of each time slot, the decision on channel access is made and executed. Therefore, the decision epoch of a mobile node is at the beginning of a time slot. The objective and the constraints satisfy the Chapman-Kolmogorov equation. In case of infeasible optimal solution, the mobile node n

will deviate from coalition S (i.e., coalition $\mathcal{S}$ is not stable). Let $\phi^*(s_n, \psi_n)$ denote the optimal solution of the LP problem.

Policy, Objective, and Constraints

The stationary channel access policy of mobile node n defines the probability of performing action in which each mobile node seeks to find a policy such that the cost of channel access is minimized while the QoS constraints are met. The maximum packet loss rate due to lack of buffer space and average packet waiting time in the queue of mobile node are maintained below the target thresholds.

Immediate packet loss rate

A packet will be dropped (i.e., lost) if the queue is full upon its arrival. For $\psi_n = 1$, packet loss will occur due to lack of space in the queue to accommodate the arriving packets. In particular, the immediate packet loss rate is given by the probability that the mobile application generates more packets than the available space in queue. Note that since a collided packet is retransmitted, packet loss occurs only due to the lack of buffer space in the mobile node.

Immediate packet waiting time

From Little's law, the average waiting time can be expressed as a function of average number of packets in the queue and average arrival rate is given by

$$\bar{W} = \lim_{t \to \infty} \frac{1}{t} \sum_{t'=1}^{t} \frac{E(B_t)}{\bar{\alpha}} \quad (10)$$

Therefore, the immediate packet waiting time at a given state s_n can be given by

$$W_n(s_{n,}, \psi_n, \pi) = \frac{s_{b,n}}{\bar{\alpha}} \quad (11)$$

Where $S_{b,n}$ is the is the number of packets in the queue. $W_n(s_{n,}, \psi_n, \pi)$ is the immediate packet waiting time at a given state s_n.

The packet arrival rate in averaged is as follows,

$$\bar{\alpha} = \sum_{a=1}^{A} a(\overrightarrow{\lambda^T}\ A_n^{(a)})\vec{1} \quad (12)$$

Immediate channel access cost

For mobile node n, the immediate channel access cost can be defined as

$$\zeta(s_n, \Psi_{n,}\pi) = w_{ac}\psi_n \quad (13)$$

Where w_{ac} is the weight corresponding to the cost of channel access. If the mobile node decides to access the channel, the immediate cost will be w_{ac} and zero otherwise. This cost can be different for different mobile nodes (e.g., cost due to energy consumption for transmission). On the other hand, this cost can be identical for all mobile nodes (e.g., cost due to price w_{ac} charged by the network operator per packet transmission in addition to the reservation price pl).

Best Response Policy

Mobile node n has the objective to minimize the stationary cost while the stationary packet loss rate and packet waiting time are maintained below the target thresholds S_n^{max} and W_n^{max} , respectively. optimization problem for individual mobile node n, is as follows

$$\min \mathcal{J}_{L,n}(\pi) \quad (14)$$

$$\min \mathcal{J}_{L,n}(\pi) \leq S_n^{max} \quad (15)$$

$$\min \mathcal{J}_{W,n} \leq W_n^{max} \quad (16)$$

Where, multi-policy π can be defined as $\pi = (\pi^{-n}|\pi^{n}) \in \boldsymbol{\pi}$ and π^{-n} is the multi-policy of all mobile nodes except mobile node n. In this optimization problem, each mobile node can optimize its own policy π_n. The policy of one mobile node will affect the cost and performance measures of other mobile nodes through the channel access probability τl, or estimated collision probabilityP_{col}. To obtain the optimal channel access policy (i.e., constrained Nash equilibrium) of all mobile nodes, a stochastic game model can be developed.

Stationary Probability and Constrained Nash Equilibrium

The stationary probability for a mobile node to be in state S_n is denoted by $q_n^{\pi}(S_n)$ for state $S_n \in \Delta_n$. This probability is obtained by solving the below equation

$$(\overrightarrow{q_n^{\pi}})^T\, P_n^{\pi} = (\overrightarrow{q_n^{\pi}})^T\,, (\overrightarrow{q_n^{\pi}})^T\, \vec{1} = \tag{17}$$

Where $(\overrightarrow{q_n^{\pi}})^T$ is the stationary probability vector of a mobile node n. P_n^{π} is the transition probability matrix when the multi-policy π is applied Nash equilibrium is obtained by the following algorithm. In this algorithm, the steps are:

1. Initialize the multi policy π.
2. The mobile nodes in the same coalition interact through the channel access probability τl, or equivalently estimated collision probability P_{col} and the best response policy will be computed iteratively. This channel access probability or collision probability is a function of multi-policy π and stationary probability $\overrightarrow{q_n^{\pi}}$. Δ is the threshold used for the termination of the algorithm.
3. The constrained Nash equilibrium is obtained from $\pi{*}= (\ldots, \pi n^{*} \ldots)$ for mobile node $n \in \mathcal{S}$.
4. Update the multi policy $\pi = (\ldots, \pi n^{*}, \ldots)$

In a stochastic game with independent states, at least one constrained Nash equilibrium exists and the algorithm will converge to one of the constrained Nash equilibria. The uniqueness of this equilibrium, however, cannot be guaranteed. At this constrained Nash equilibrium, none of the mobile nodes can reduce its cost given that the other mobile nodes do not change their strategies. In addition, the equilibrium can be selected from the set of constrained Nash equilibrium such that the best performance can be achieved.

Performance Measures

With the stationary probabilities (when the stationary multi-policy π is applied), different performance measures for mobile node n in coalition $\mathcal{S}$ can be obtained. The average number of packets in the queue of mobile node n can be obtained from

$$\overline{b_n} = \sum_{S_{b,n=1}}^{n} S_{b,n}\big(\sum_{S_{l,n\in L}} \sum_{S_{h,n=1}}^{H} q_n^{\pi}\,(S_n)\big) \tag{18}$$

Where, $S_{b,n,l}$ is the number of packets in the queue in the location l. $S_{h,n}$ is the phase of packet arrival respectively. $q_n^{\pi}(S_n)$ is the stationary probability. The packet loss rate is given by

$$S_n = \sum_{S_{n,\psi_{n\epsilon\Delta_{n\times\psi}}}} \mathcal{J}(s_{n,}\,\psi_{n,}\pi^{*})\,\pi_n^{*}(\tfrac{\psi_n}{s_n})q_n^{\pi}(s_n) \tag{19}$$

Where, S_n is the average packet loss rate. $\mathcal{J}(s_{n,}\psi_n,\pi^{*})$ is the stationary cost, loss and waiting time functions. p_n^{*} is the best response policy. $q_n^{\pi}(s_n)$ is the stationary probability.

Finally, the cost of the channel access can be obtained from the given equation

$$\overline{\mathrm{C_{ac,n}}} = \sum_{(s_{n,}\psi_n)\,\epsilon\Delta_{n\times\psi}}\big(\sum_{(s_{n,}\psi_n)\,\epsilon\Delta_{n\times\psi}}\big(\varrho(S_n,\psi_{n,}\pi^{*})\pi_n^{*}(\psi_n)q_n^{\pi}(S_n)\big) \tag{20}$$

The average packet waiting time is given by

$$\overline{W_n} = \frac{\overline{b_n}}{\overline{\alpha}(1-S_n)} \tag{21}$$

Where, $\overline{W_n}$ is the average packet waiting time. b_n is the averaged no. of packets in the queue of mobile node *n*. The channel access probability, which is used by other mobile node to compute best response policy, is obtained from the equation of finding the channel access probability.

PROPOSED SYSTEM MODEL AND ASSUMPTIONS

The proposed system model makes the consideration of the system for the analysis of congestion occurrence in the network and load payoff, and this section discusses traffic generation and wireless transmission, mobility model, channel adaptation, channel access and stable network formation using game theory.

Traffic Generation and Wireless Transmission

The packet generation process (or the packet arrival at the queue of a mobile node) is modeled as a batch Markovian process with H phases. The probability of transition matrix for the arrival packet process is given by $A_n^{(a)}$ for a ∈ {0, 1. . . A} arriving packets, where A is the maximum batch size. The element at row *h* and column *h′* of matrix $A_n^{(a)}$ is denoted by $\alpha_n^{(a)}(h, h')$ which represents the probability that a packets arrive at the queue of the mobile node and the phase changes from h to h'.

Service area which is divided into multiple cells (i.e., locations) considered. The set of locations in this service area is denoted by L. At each location, there is one base station. There are N nodes transmitting data to base stations using a reserved channel. The set of all mobile nodes is denoted as N. A fixed price of *pl* monetary units (MUs) is charged for reserving a channel that will potentially be used for communication with the base station at location *l* ∈ L (Figure 2)

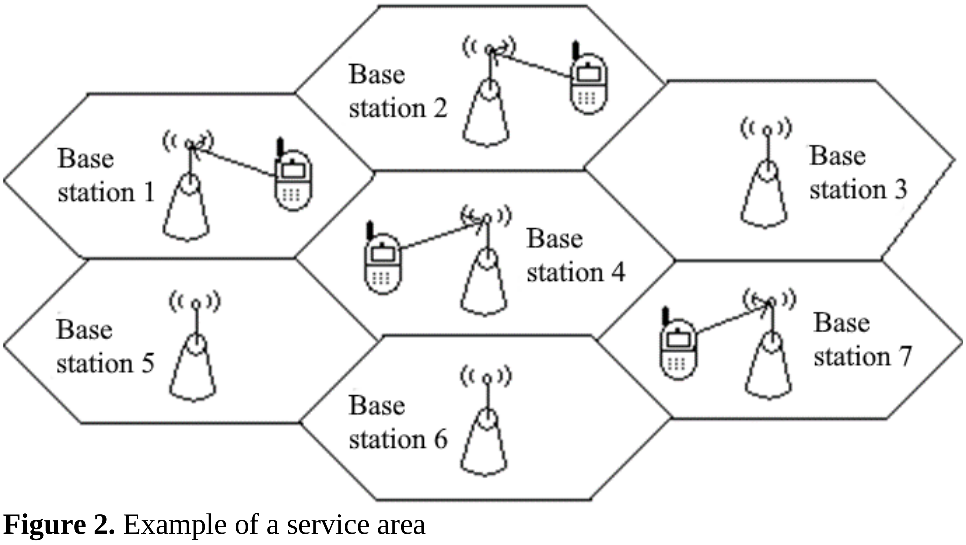

Figure 2. Example of a service area

A time-slotted transmission scenario is considered. Each mobile node has a finite queue of length *B* packets used to store the data generated by the mobile application. The packets are retrieved in the first-in first-out (FIFO) fashion and transmitted to the base station using adaptive modulation. With a maximum of F transmission modes, the transmission mode f is used when the instantaneous SNR in one time slot falls into interval f. Note that the time slot refers to the time required for transmission of one packet using the basic transmission mode which includes the duration of contention and acknowledgment period. With adaptive modulation, the probability that c ∈ C= {0, . . . ,} packets are successfully transmitted from a mobile node to the base station at location l is denoted by $\mu_l(c)$. Here C is the set of available transmission rates. The QoS measures of mobile node n are the maximum packet loss rate and the maximum average packet waiting times which are denoted by S_n^{max} and W_n^{max}, respectively.

Mobility Model

Each mobile node has a finite queue of length *B* packets used to store the data generated by the mobile application. The packets are retrieved in the First-in First-Out (FIFO) fashion and transmitted to the base station using adaptive modulation. With a maximum of F transmission modes, the transmission mode *f* is used when the instantaneous SNR in one timeslot falls into interval f. In mode *f*, *cf* packets can be transmitted in one time slot. Note that the time slot refers to the time required for transmission of one packet using the basic transmission mode which includes the duration of contention and acknowledgment period.

With adaptive modulation, the probability that $c \in$ C= {0, . . . , *cf*} packets are successfully transmitted from a mobile node to the base station at location $l$is denoted by μl(c), which can be obtained given the average SNR γl. Here C is the set of available transmission rates. The QoS measures of mobile node n are the maximum packet loss rate and the maximum average packet waiting time which is denoted by Smax and Wmax, respectively. For movement node n, the mobility is modeled in such a way by an transition matrix Mn. The element are row matrics l and column l' is denoted by $M_n(l, l')$ for $l,l' \in \{1 .....l'\}$ where L= /L/ is the total number of locations in the service area, and /L/ is the cardinality of set L. The $M_n(l, l')$ element represents the probability that the mobile node changes its location from l to $1'$

Algorithm for Joint Channel Reservation Sharing and Channel Access

The cost ζn, for any mobile node n, is composed of the cost of channel reservation (i.e., which is a function of price pl charged by network operator) and the cost of channel access (i.e., Cac,). By this algorithm the joint channel reservation sharing and channel access methods are developed.

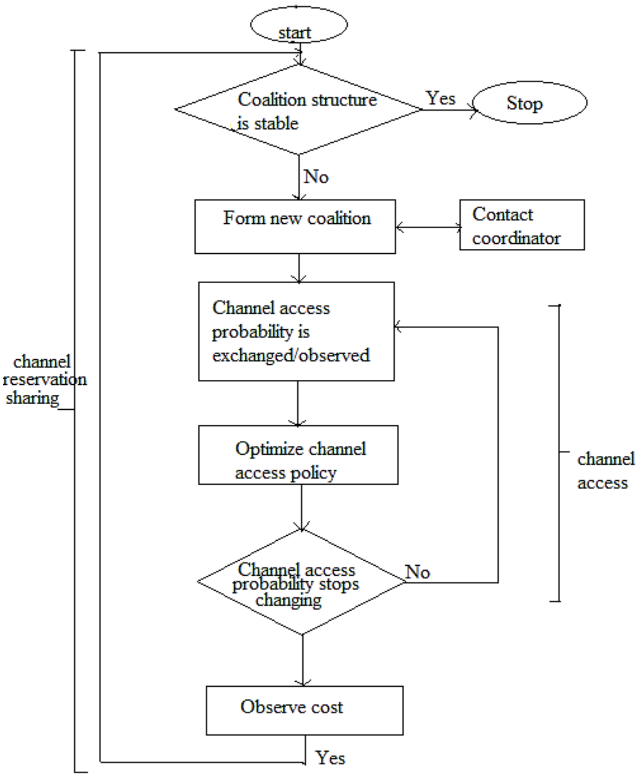

Figure 3. Flowchart of channel reservation and channel access.

The proposed algorithm for joint channel reservation sharing and channel access to minimize the cost of wireless access for a mobile node is shown in Figure 3.

1. First, a mobile node contacts the coordinator to obtain information about active mobile nodes. This information is used to form a coalition.
2. Once a coalition is formed, the channel access mechanism is executed.
3. The estimated channel access probability or collision probability is used to obtain the best response policy of the mobile node.
4. The best response policy ensures that the channel access cost Cac, is minimized while the QoS requirements are met. Then, the mobile node proceeds to compute the cost due to channel access and form a new coalition if necessary.
5. The channel access policy is adapted in a time scale smaller than that during which the coalition formation decision is made (using the information from the channel access policy).

Adaptation of channel access strategy

With coalition {1, 2, 3, 4} (i.e., all four vehicles share the reserved channel) the channel access probabilities of these vehicles are in each iterations can be formulated. Given the initial channel access probability, the channel access policies of all vehicles converge to the constrained Nash equilibrium. At this constrained Nash equilibrium, the packet loss rate and the average packet waiting time are maintained below the target thresholds S_n^{max} and W_n^{max}, respectively.

Effect of mobility diversity on channel access

The mobility diversity can be exploited to share a reserved channel for wireless access to base station. It is observed that at a lower price each vehicle achieves the lowest total cost when the reserved channel is not shared with other vehicles. If there is no sharing, there is no collision. As a result, the cost due to channel access is small. However, as the price increases, it is better for vehicle to share the reserved channel to reduce the total cost. The total cost is minimized if vehicle shares the reserved channel with another one vehicle. As the price increases, the number of vehicles to be in the same coalition (to share the reserved channel with vehicle) will increase to minimize the cost.

If any one member of a vehicle in a coalition is shared with two other members, the probability for vehicle to be at locations 1 and 2 is varied. Note that for the vehicles, the probability to be at locations 3, 4, and 7 will be varied accordingly. As this probability to be at locations 1 and 2 increases, vehicle has a higher chance to be at the same location. Given this varying mobility parameter for any other vehicle, the total cost of vehicle can be minimized if different coalitions are formed.

Stable coalition formation for channel reservation sharing

The state transition diagram of the coalition formation process among 4 vehicles is considered for example. There are a total of 15 states with different coalitional structures. These states can be divided into four groups with the total number of coalitions (in a coalitional structure) ranging from one to four. In the first group with four coalitions, none of the vehicles cooperates (i.e., $\omega_1 = \{\{1\}, \{2\}, \{3\}, \{4\}\}$). In the second group with three coalitions, only two vehicles form one coalition (e.g., $\omega_2 = \{\{1, 2\}, \{3\}, \{4\}\}$). In the third group with two coalitions per coalitional structure, the vehicles can form two coalitions with each coalition having two vehicles (e.g., $\omega_8 = \{\{1, 2\}, \{3, 4\}\}$).

Alternatively, a structure composed of two coalitions can have a coalition with three vehicles and another with one vehicle (e.g., $\omega_8 = \{\{1, 2, 3\}, \{4\}\}$). The fourth group corresponds to the dominant coalition (i.e., $\omega_{15} = \{\{1, 2, 3, 4\}\}$). Since the cost for the vehicles without coalition is large due to the price of reserved channel, the vehicles will gradually form coalitions in order to reduce the wireless access cost. The coalition state which yields the lowest total cost will be adopted (i.e., ω_8, ω_9, ω_{11}, and ω_{12}). Although ω_8 and ω_9 have the same number of members in the coalitions, the transient state probability of ω_9 is larger than that of ω_8. This is due to the fact that the total costs of ω_9 and ω_{12} are lower than those of ω_8 and ω_{11}, respectively. It is observed that there is a delay (of several minutes) in the coalition formation process before the system reaches the steady state. However, once the stable coalition is reached, the vehicles can rely on this coalition until the network state changes.

Optimal coalition structure

For comparison purpose, the case of optimal coalition formation is considered which is achieved in a centralized fashion if the coordinator can control the decision of all vehicles. A number of nodes can cooperate to form coalitional structure which minimizes the negative social welfare (total cost) instead of their individual cost.

The coalitional optimal structure is as

$$\omega^* = \{S_1^* \ldots\ldots S_J^*\} = \arg min \sum_{n \epsilon N} \varsigma_n \,(S_j^{(n)} \quad (22)$$

To obtain the optimal coalition structure, a Markov chain model is formulated to obtain the coalitional optimal model and the state space is formulated by

$$\Omega = \{(\omega_x): x = \{1, \ldots, D_N\}\} \quad (23)$$

Where, Ω denotes the state space. ω_x represents a coalitional structure The state transition $Q_{\omega,\omega'}$ can be obtained by using above equation. However, the best response policy is obtained by using the derived equation.

With the stationary probability, the total cost of all mobile nodes can be calculated by

$$\overline{C_{total}} = \sum_{x=1}^{D_N} \theta_{\omega_x} \sum_{S_{j\epsilon\omega_x}} \sum_{n\epsilon S_j} \varsigma_n \,(S_j) \quad (24)$$

Where, D_N is the Bell number. θ_{ω_x} is the stationary probability. $\overline{C_{total}}$ is the total cost of all mobile nodes.

NON-COOPERATIVE GAME MODEL

In stochastic and coalitional game theory, the resources are sharable, which gives payoffs to all mobile nodes. In this game theory if there is no sharing of resources, the payoffs are further diminished. So, a safer strategy of lower cost display is dominant strategy which is called as perfect Nash Equilibrium strategy which has some advantages over Nash Equilibrium. This strategy is accomplished by the war of attrition game It is a game analyzed in the game theory, when the mobile node does not cooperate. A strategy profile $S_1^* \ldots\ldots S_n^*$ is a Nash Equilibrium if for each $S_i \in S_{-i}$.

Dominant Strategy

A dominant strategy occurs when one strategy is better than other strategy for one player which always provides lower payoff than other strategy The strategy space is denoted by,

$$S_n = S_1 \times S_2 \times S_3 \times S_{n-1} \times S_{n+1} \times \ldots\ldots S_N \quad (25)$$

Where S_n is the strategy space for all mobile nodes n. S_N is the strategy for n^{th} player which is strictly dominant.

RESULTS AND DISCUSSION

The generation of wireless nodes using MATLAB simulation was obtained from this graph is shown in Figure 4. In this totally 20 nodes are used. Here the mobile nodes randomly move from one location to another location.

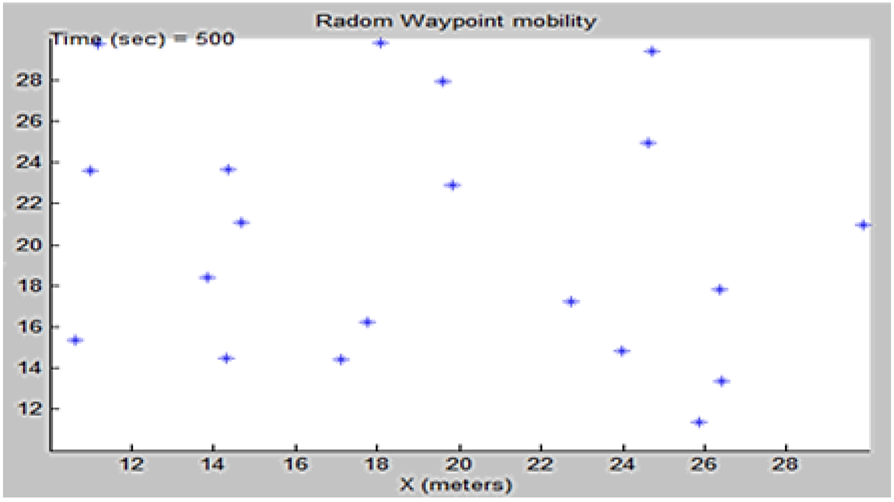

Figure 4. Generation of wireless nodes by using random way mobility model.

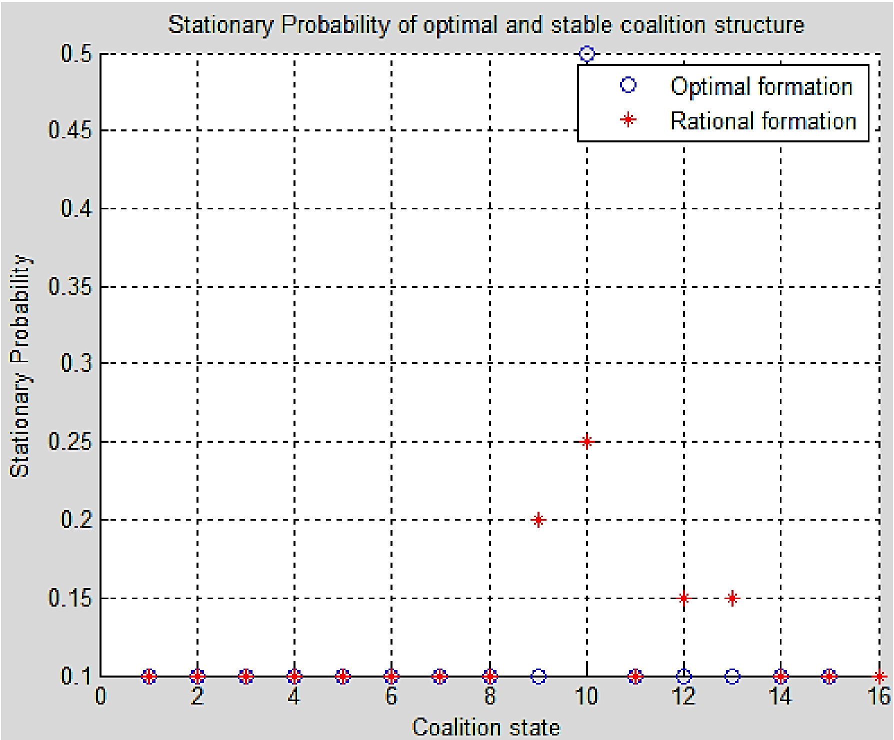

Figure 5. Stationary probabilities for both optimal and stable coalitional structure.

In this, the stationary probabilities of the coalitional structures at the steady state are shown in Figure 5 for both optimal and stable coalition formation was obtained using MATLAB simulation. In this, there are multiple stable coalitional structures.

In this, the average cost of all vehicles for both stable and optimal coalition formations is obtained using MATLAB simulation is shown in Figure 6. The optimal and stable coalitional structure achieves lowest cost in presence of coalition. Dominant coalitional structure achieves lowest average cost than the stable and optimal coalitional structure if the resources are not sharable. In the non-cooperative case, mobility does not affect the cost since each vehicle has its own reserved channel and there is no packet collision during data transmission. As the speed of vehicles at each location increases, there is no packet collision and the cost decreases.

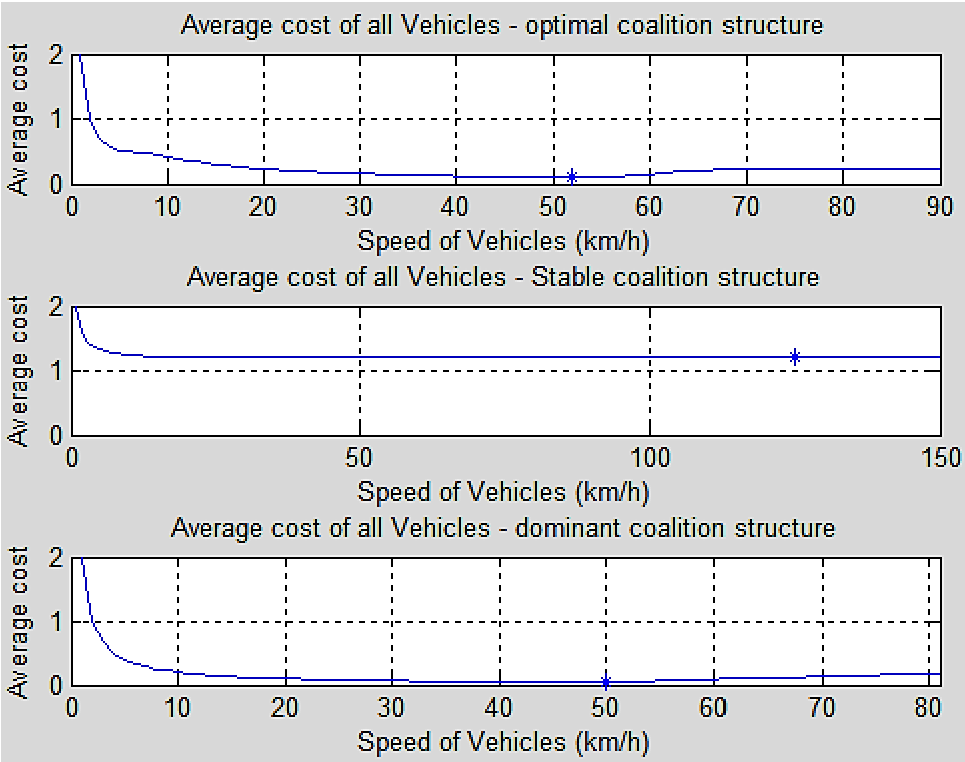

Figure 6. Average cost of all vehicles (i.e., mobile nodes) under stable, optimal and dominant coalitional structures.

CONCLUSION

This work intended to structured an wireless communication access for mobile devices for the reduction of transmission cost and achieves higher quality of services by considering the factors such as packet loss rate and minimizing the averaged waiting time. By exploiting mobility diversity among multiple mobile nodes, the channel utilization can be improved and the cost of the wireless access can be reduced by sharing the reserved channel. The accuracy of random way point mobility is simulated and verified using MATLAB simulation. Based on the location obtained from mobility model, a coalition will be formed by sharing the channel reservation among multiple mobile nodes and so the cost of the wireless access is reduced under stable and optimal structures**.** The result obtained is compared with the non-cooperative game theory under dominant structure in which there is no sharing of resources among multiple mobile nodes. Finally, the dominant strategy provides lower payoff than stable and optimal strategy.

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