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Cooperative game theory approaches to manage traffic congestion in wireless network *

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Abstract Presently more and more advanced technology enabled mobile devices are in demand and the numbers of their users are also increasing day by day. These mobile devices having so many features assembled in them demand various types of services and larger bandwidth requirements from cellular operators for their users. For satisfying the demands of their subscribers the service providers are continuously trying to introduce the newer upgraded technologies. Today the user is using so many devices having different service requirements and various capacities enabled wireless networks at the same time. Collectively all these requirements together put tremendous stress on the network traffic and this situation often leads to network congestions. Congestion is a point at which the network resources of the service provider experience stress and all services are degraded and they often collapse after some time. In the cellular network the resources are uniformly distributed but some networks are heavily loaded and others are less. So some have shortages and they need to cooperate with their adjacent neighbors, but many neighbors having their own sufficient resources are many a times not willing to cooperative with the lesser efficient ones. To solve this issue we propose a noble cooperative approach based congestion management scheme in this paper that minimizes congestion in a network. Our prime motive is to minimize the congestion level so that the new call and handoff calls are to be served. In this schema we can reduce the congestion so that the resources are utilized effectively to satisfy the users' demands and the qualities of services delivered are also improved.

Key words Congestion, bandwidth, game theory, communication.

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1 Introduction

As newly incoming mobile generations are evolving, they demands wide range of services like broadband, Wifi, WiMax, etc. The accessing services were not only technologically different but also demands various range of bandwidth requirements. Its seems that with the increase of heterogeneous services for wireless network service access technologies includes providing the broadband, UMTS, GSM, WiFi, WiMAX, etc. facilities by the same service provider cell subscriber [1] . Recently, much research works has been done with the aim of combining these technological different accessing methods under single operational level having wide range of services to be provided, with larger bandwidth requirements, more coverage area, low operational costing, and quality of service (QoS) to fulfill the users' demands. In the starting the several network subscribers have tried so far to intensify their wide services ranges by increasing the frequency bands in order to serve and facilitate those unmatched devices. Instead of serving so many heterogeneous services accessing by devices, the problem paradigm shifted to resource utilization which further states to degrade the (QoS) within the network [2]. Lot of valuable research has been done in improving handovers and resources management to improve the (QoS) to satisfy the user expectation but it hasn't matched the desired level of satisfaction so far. Now most of the work is done in service adaptation section in matching so many different variants of network modules and servicing concentrated on single serve service by network interface for all range of applications within the same time where the user demands for various types of access services for their variant application facilities through the network provider at the same time within best of known (QoS) [3, 4].

During the recent times the researchers are investigating to find some possibility to access through multiple applications from common resources that would be distributed in between them. Some research projects are initiated with splitting the resource schema for different service required format needs for so many applications in real time [5,6]. In this field success has been reported in successful serving lots of nodes demands having variant applications using different categorical resource modules from same available recourse at the same time. In this process same resource would split and be intensified to same node's serving various mode applications [7]. The researchers have also investigated the issue of using multiple radio access technologies (RATs) simultaneously at the terminal, concluding that parallel transmission over multiple RATs by a carefully run successful resource allocation scheme allowing one to achieve a high throughput as the throughput sum is obtained by the use of each individual accessing technology.

Game theory is the branch of mathematics that deals with the interaction of independent autonomous agents (clever, selfish, greedy) [3]. There are two different approaches in game theory depending on whether the interest is focused on the individual agents (non-cooperative) or in a coalition / group of agents (cooperative). We are here interested in the later one (cooperative), where agents benefit from the cooperation with other agents by forming coalitions. Some of the fields where it has been applied for forming coalitions include the interference minimization, code and power selection, rate optimization, spectrum sharing in cognitive radio, cross-layer optimization or infrastructure management among others [4, 5].

The use of game theory for Multi-Radio Resource Management (MRRM) in incoming generations network is not a new concept. Researchers have applied both cooperative [8,9] and non-cooperative / competitive game models [10–12] to obtain efficient resource allocation schemes. They have successfully provided a comparison between non-cooperative and cooperative models in resource allocation and further being demonstrated that the collaborative strategies are able to improve the overall system performance [13]. Most relevant work among those listed above being [8] which uses a bankruptcy game to model for resource allocation problem, but applies as different solution method and is also confined to some limiting scenario as regards the composition of available access technologies. We evolve here a comparison among those applying our resource allocation to the scenario as described in [8]. In this paper, we address the issue relating multi-radio resource allocation in generic heterogeneous wireless networks. As the workers in [13] use a cooperative game approach, where several network technologies cooperating with each other in order to attain the ultimate goal of user satisfaction, we use the bankruptcy model [8] and apply Kalai-Smorodinsky-Barganing Solution (KSBS) to find some distribution rule that perfectly fits into our objective in simultaneous resource allocation schema over various channel requests [14]. We also provide extensions of our approach to handle the mobility of users between coverage areas with different compositions of access technologies.

2 Literature review

In recent decades, the game theory is widely used for analyzing various resources management problems of networks communication [15]. Generally, both branches of the game theory, cooperative and non-cooperative are used for dealing with the network related activities [16]. Non-cooperative game theory is found to be appropriate in studying the strategic options actions to be chosen when various competitors participating in a game and competitors as game players choose their own courses of strategy independently of others to improve their own profits or minimize their losses. The main game theory for recent research in networks communication is focused on the use of the non-cooperative games approach for so many applications and distributed resources, various allocation policies [18], network congestion management [19], power management [6] and frequency band sharing of radio resources, among others. The non-cooperative game deals with competitive scenarios as compared to the cooperative game study analytical tools to understand the rational behavior of strategic players when they are willing to cooperate under a coalition formation [15–17]. In this paper approaches restrict only to coalitional theory and some other references including bargaining type games under shadow of some cooperative games theory.

Recently, a lot of research work has been done in cooperative theory fusing with new networking schema that has a drastic improvement in performance for networking layers [18, 20, 21]. But in the path of implementation of cooperation game theories for ideal communication networks services serious challenges and various issues regarding such fair resource management and modeling among others have arisen and coalitional games proved to the best effective tool for designing efficient and effective cooperation game polices for networks communication. In network communication research field most of the authors are currently restricting themselves to applying the standard of coalitional game theory models and policies to analyze various limiting aspects of cooperation possible within networks [15–17]. In this paper our prime aim is to develop a unified model of coalitional game theory oriented towards solving network resource management problems.

While investigating the resource allocation problem for several different network organizations using the cooperative game like Stackelberg theory [22] it is to be noted that this theory allows every individual network operator to formulate and resolve resource allocation problem through cooperative game approach in which they cooperate with others by coalition formation for maximum utilization of resources available within them. Each and every member within coalition formation is allowed to access some of the resources that are requested according to their own operational constraints. In various network resource allocation schemes this issue is addressed through the most efficient manner for that service via networking delivery [23]. In those designs the fault tolerance architecture is provided to maintain uniform (QoS) support for the network failures [24]. It is formed of certain level of fault tolerance schema that allow the users to access any one of them among various available wireless networks. When multiple networks access options are available for a mobile user and he has to decide his service on the basis of his priorities enabling hands-off and other services level among one of these available network, he naturally chooses the best option available to him. A resource reservation approach strategy found that resource handling through single handedness is unable to manage the resource allocation policy so to overcome these type of limitations, the final solution is to spread all resources and applications among several networks [25].

Some researchers use other different approaches to address the resource sharing problem. In previous works they focused on effective strategies on either minimizing resource shortage or maximizing the resource availability. In an another approach this problem was tackled through the Nash bargaining game solution (NBS) in which an optimal allocation policy is applied for system resources under cooperative assumption among different participating nodes. In recent works the researchers have adopted a smart bargaining game strategy, derived from the pure game theory approaches, which is based on the Kalai and Smorodinsky game models [26]. In the past KSBS was widely used for different types of resource allocation and management problems. However, our proposed approach is a good combination of the different game strategies to offer every coalition participant, who, being always in profit if they formed a collation, to share the distributed resources of the network system as their requirements demanded [27–33].

3 System model

3.1 A non-cooperative game theory

A non cooperative game theory is basically a game strategy and in mathematical form this could be represented by itself along with its associated components like, the players, game strategies and payoff or outcomes by mathematical set model. In formal language the strategy of game could be defined as:

$$G = (N, S_i, u_i) \in N \tag{3.1}$$

where, N is a finite set of participating players in the game, i.e., $N = \{1, \ldots, n : n \in \mathbb{N}\}$, S_i is the set of strategies available for the participating player i, $u_i : S \to R$ is the function of the outcomes of the game (payoffs) for the player i, and S is the Cartesian product of the strategy sets defined by $S = S_1 \times \ldots \times S_i \times \ldots \times S_N$.

3.2 Cooperative coalitional based game theory

A coalitional game theory is a form of cooperative game $G(N, v)$ and is defined by a finite set of participating players N and a payoff function v which assigns an outcome value to the coalition formation by the players within the participant set N. This type of games have certain characteristics in which the payoff value of a coalition form completely depends on the coalition formation members and not on the outside non coalition members participating in the game. In such games, the games characteristic could further be distinguished into the Transferable Utility function (TU) games and the Non-Transferable Utility function games (NTU). In TU type games the utility function outcome v maps to some real number value and these values could be distributed as a fine share among each of the participating coalition members, whereas, in NTU type games the utility function v does not map to any single real value but into a finite set of payoff vectors [3]. Thus the game payoff for each player that he receives within one coalition depends on the joint actions that the players take.

A main assumption associated with the classical coalitional game theory based problems is that the game is superadditive in nature, that is,

$$v(A \cup B) \geq v(A) + v(B) \tag{3.2}$$

where, A and B are two disjoint coalitions for a game. This reflects that by increasing the size of the coalition for any game strategy is always beneficial and thus, the grand coalition formation could guarantee for a win or a massive benefit for all the players (cooperative coalition among them). In many problems, however, the superadditive nature of the games characteristic doesn't hold due to the association of some cost related formalities of the coalition formation. Under such circumstances and cooperation requirement a grand coalition wouldn't be formed. In such adverse situation a coalition formation becomes a massive challenging issue and even it is totally hard to force the players to cooperate for a coalition formation. In [6] a general framework for coalition formation is proposed that has been applied to wireless communication problems like beam forming and cognitive radio [8]. We follow here the general framework of [6] but apply our positioning to the game.

3.3 Bargaining theory

Bargaining theory is also a game theory related to cooperative games theory through the concept of Nash bargaining theory. In this theory context, we consider two players and label them as $i, (i = 1, 2)$, such that both are trying to come to an agreement over an outcome in a defined set space X. Each participant as player i has a payoff function u_i that is also defined over the set space $X \cup \{D\}$, where D is the final outcome if these two participating players fail to achieve an agreement or the disagreement as outcome. The defined set as space S consists of all possible payoffs for both the participating players that they could achieve is defined as

$$S = \{(u_1(x_1), u_2(x_2)) \,|\, x = (x_1, x_2) \in X\} \tag{3.3}$$

Furthermore this could be redefined as a pair $d = (d_1, d_2)$ with $d_1 = u_1(D)$ and $d_2 = u_2(D)$ for the mutually disagreement point or the threat point. Subsequently, a bargaining problem is defined as the pair (S, d) where S is a closed subset of rational set R and $S \subset R^2$ and $d \in S$ such that S is a convex and compact set and their exists some $s \in S$ such that $s > d$, i.e., $s_1 > d_1$ and $s_2 > d_2$ (referencing some feasibility property from the bargaining problem definition).

The first and the best ever known example of a bargaining rule is given by Nash. The Nash rule chosen for each bargaining problem $(S, d) \in B$ by an individually rational alternative where B is a rational set related in such a way that it maximizes the product of the agent gains from the disagreement is written as

$$N(S,d) = \arg\ \max_{x \in I(S,d)} \prod_{i=1}^{n} (x_i - d_i) \tag{3.4}$$

3.4 The Egalitarian rule

According to the Egalitarian rule by Kalai [26] some prime choose for such type of problems $(S, d) \in B$ so that its maximum individual rational payoff of each of the problem that gives each and every agent an equal gain share from his disagreement payoff :

$$E(S,d) = \arg \max_{x \in I(S,d)} \left(\min_{x \in (1,\ldots,n)} (x_i - d_i)\right) \tag{3.5}$$

Geometrically for each problem $E(S, d)$ is the intersectional boundary of S and its half line which starts from d and passes through $d + (1, \ldots, 1)$.

Canzian et al. [34] in their research successfully demonstrated the efficacy of the sub-game strategy of different opponents, with a given particular type accessible point strategy option, under unique Nash equilibrium game in which almost one among them satisfies the Stackelberg equilibrium and that particular equilibrium is perfectly equivalent in the network performance. In their paper [34] Canzian et al. assumed that the outcome of each i^{th} user $\phi_i(B_i, E_i)$ will continuously increase the data rate B_i and further decrease the energy consumption E_i, where B_i and E_i represent the variations in those quantities relative to the no-cooperation case, each ϕ_i can be expressed as a sum of contributions from each other user $\phi_{ij}(B_{ij}, E_{ij})$, that is,

$$\phi_i(B_i, E_i) = \sum_{j \in u \setminus \{i\}} \phi_{ij}(B_{ij}, E_{ij}) \tag{3.6}$$

where, U is the set containing all users as its elements. But Canzian et al. [34] were unable to clearly show exactly how to measure the access point as a network performer, they only assert that all the users have the options regarding their outcomes via a defined function which may be upper semi-continuous. This strategic policy makes their outcomes more powerful even when opting for a particular result measures like reburied data rate own self.

Here we compare the simulation results of such game theory systems which are inspired by voluntary cooperation which leads from the no cooperation scheme to a motivational forced cooperation scheme where the participants are required to cooperate to from a coalition that deals with the access point optimization. The coalition finds better throughputs for the participants and their outcomes since the participant with the weakest resources gets much significant throughput from the voluntary cooperation as compared to the forced cooperation. This motivation leads the participants to from a coalition which leads to much better results. The overall summary of this research is that the forceful coalition motivates the overloaded resource participant to cooperate with low resource participant and when any emergency situation of the shortness of resources arises the coalition would come forward to support him with others' coalition. The users with strong channels get rewards and overcome any shortages and the weaker also gets the best rewards. However, since the participants with abundant resources also use more power and further the weaker also overcomes the shortages, this results into both getting the same profit in terms of the outcome.

3.5 Cooperative coalition formation

The coalition formation is a dynamic process. The process of new members joining the group and the older members leaving it occurs periodically. In the initial stage it starts with few numbers of players to form a coalition. As the time elapses, the collection of coalitions $S = \{S_1, \ldots, S_k\}$ can merge into a larger coalition if the merger yields a preferred collection.

Similarly, a coalition would split into smaller coalitions if the splitting yields a preferred collection. Coalitions will merge only if at least one member of coalition is able to strictly improve its individual utility through this merger (or split) without decreasing the other players' utilities. Thus it is more beneficial to include merge-and-split rules in coalition formation algorithm.

But in practical the coalition stability is a bigger issue for the researcher because everyone thinks of if his own profit and even when any voluntary coalition formation takes place it takes some time and without any profit, the question then arises as to how could any organization stand in a competitive situation. Here the cooperative nature cannot bind or guarantee for others to be bound together by stability for long time. So we search some policy or mechanism to inspire or motivate the participants to form a coalition and so that the resulting coalition would also be stabilized.

4 Assumption model

In the real world the mobile network service provider having installation architecture at a known location to provide service to his customers having various capacity of resources to support his users. At a certain location or for certain durations for the subscribers of a network the service providers resources may vary and at some times their resources may get short which leads to a rise in the rate of call drops or degradation of services.
To resolve the problems of call drops and quality of service degradation various strategies are adopted. Some of them are inspired from game theory based strategies. Researchers find that the game theory could best model this type of situation where variation of resources and a competitive situation - where every vendor tries to provide the best services to its end user for resolving these hindrances. Both the Bargain theory and the Kalai and Smorodinsky models are some of the game theory models under cooperative strategies environment building situation which have been somewhat successful to effectively handle such type of problems in a competitive environment having limited or scanty resources. In this situation some network subscribers try to make a coalition and but other groups also try to makes their own coalitions. Keeping pure profit and competition these coalition groups again compete with other such groups and under such strategies that some dissatisfied or ambitious partners make a split in the existing coalitions and new coalition formation takes place and that finally leads to a hang or an unstable situation. This instability cannot give good outcomes for the subscriber, therefore, the researchers try to find suitable theories leading to stability in the coalition.
Here we present a new theory of cooperative bargaining that helps build a bigger and stable coalition which would be long lasting for the competitive and ambitious partner and which also handles the critical resource problem and the peak state overloading to minimize the call drop and quality degradation.
The cooperative theory simply works on the principle that the weaker players, understanding their weakness and limitation, for trying situations related to their survival in the market form association with other participants to overcome their weakness against the more powerful competitors to remain in the game or to compete with a better optional strategy. Sometimes the players form a coalition to maximize their profit which is not possible if they play individually. While in coalition each player does not necessarily remain loyal to his group and he is always in search of better options to maximize his own profit. There are some other unsatisfied partners in the coalition who are not getting some fair share of their profits while the others consume larger chucks of profit at the very same time. Such types of situation destabilize the coalition and it gets fragmented and new coalitions are formed but the newly formed coalitions also do not guarantee for their stability.
The cooperative theory says that the weaker players in the game search for a better option and a coalition is made to bargain in the game. This has one more problem that a stronger player does not form any coalition because he is earning a large profit and does not want to share its resources with others and allow others to earn profit too. The stronger one is enough to play his game separately on his own and save his earnings to be invested for more profit earning resources.
Here, understating the limitations of the cooperative theories we present a fair cooperative game theory that is much stable than the other known theories and it surely guarantees the stability of the coalition along with an attraction to form a bigger group in which each player has a guaranteed assurance of finding his share of the profit. The best point in our proposed theory is that it has the ability to bear real time critical resource availability and it solves the problem of tackling the peak time work load.
First we focus on the previously available theories of game given in (3.1) which states that it is better to form a coalition. This coalition with cooperative attitude not only flourishes much better in the competitive scenario to compete with the other opponents having smart game strategies but also provides them a chance to maximize their profit by pooling together their resources. Further we propose a new environment or situation where a much stronger player is ready to group together with some weaker players and to cooperate with them.

Our proposed equation is still inspired from the bargain game theory that brings the powerful player to cooperate with the weak player. Here the barraging is that the stronger player is willing to cooperate and unite with the weaker one to play a more dominant role in the game. (4.1) guarantees that each participant first cooperates with others by giving its resources to the other having lesser ones and only the left one are used by himself and this is followed by everyone in the group as a cooperative bargaining with extra resources being shared among them all.
In many situations one service provider having larger resources as compared to the other service providers but at other places or at peak times its resources are exhausted more than those of its neighbors, then if it follows strategies as directed by (3.2) then it gets its neighbors' resources to be utilized for its users as determined by the following relation:

$$f\left(R\left(x,y\right)\right)=S\left(x\right)+\sum\nolimits_{y\subseteq x}D\left(y\right), \tag{4.1}$$

where, f is the coalition system as R is the cooperative collection of resources having x amount of resource sufficient for the owners themselves and y is the surplus resources distributed among the needed participants. S is the owner of resource that first donates its all resource to coalition and then request resource for its own uses and D are the coalition participants among whom the total collective resources as donation are being distributed including the acceptors and the donors in the group.

4.1 Call admit control policy

The call admits control policy in this paper processes on availability of resources within the coalition under interested participant in that geographical network coverage area. Any new call could be admitted if any free resource is available form a coalition group to support the call. Since donate first and then utilize remaning policy for processing the new call admitting policy so each participant first donates and then utilizes its resources policy which makes a fair availability and utilization policy to process the calls having versatile requirements.

4.2 Resource handover

The resource collection distribution and utilization related issues also arise when a user moves form one cellular cell area to another. When the users utilizing certain resource services in one network cellular location move to another location this generates a new bargaining problem which generally occurs in real life as the demographic changes occur. One user who is subscriber to a certain cellular service provider in one region and utilizes some of the resources/facilities of that service provider in that region, when he migrates to another region he has either to leave his previous service provider for want of the non-availability of the resourceful services of that older service provider in his new region and if he wants to enjoy the very same facilities that he was using at his previous place of residence then each time when the subscriber moves to a newer location in which no coalition of his previous cellular network service provider exists then he has to bargain every time for enjoying the previously utilized resources/facilities by him. The call admits policy we propose now keeps the track of every movement of each of its user in the coalition coverage area so that no subscriber is deprived of the usage of any useful service that he was previously using on his movement from one area to another.

5 Simulation and analysis

Here we propose a model for simulation purpose having some specifications and considerations. We consider a cellular subscriber moving in different geographical network coverage areas having lot of network enabled services and facilities for users some of which are Broadband, VLAN, WLAN and WiMax with connecting speeds of 4Mbps, 10 Mbps 30Mbps. Here, the network service provider has normal data speed of 30 Mbps for support and arrangements to support up to a maximum of 40 Mbps data speed to provide his services to the subscribers. Three cellular networks are normal and three having a coalition policy to serve the above mentioned four access technologies in their coverage area. In real time at congestion stage each network reaches its saturated point and no resources are available to serve further any more. If one service provider requests these services for its subscribers it needs more resources than are available. If the network service providers have coalition then they have enough resources to serve their users and provide them their demanded services. Here the mobile network collectively utilizes the resources and this results in the efficient usage of desired services by many different cellular operators in different areas and which also leads to the more availability of resources

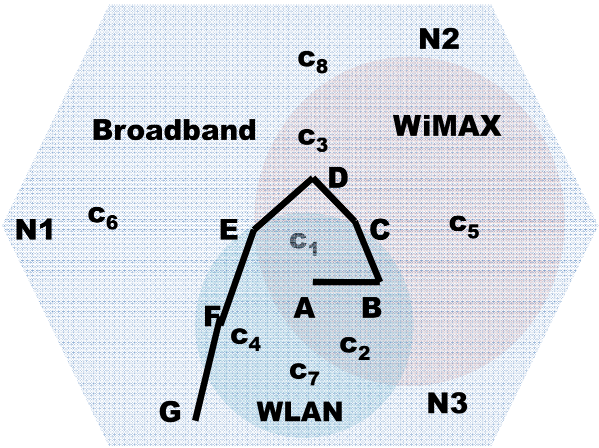

Fig. 1: Network subscribers coverage.

under adverse conditions in the saturated areas. We simulate the model to analyze the performance of the proposed policy to admit control and resource utilization under both the normal and the adverse conditions. Our model also analyzes the behavior of different players under this policy.

5.1 Result and assessment

We demonstrate our model for study with four network coverage subscribers having four different services along with resourses analogous to real time event happening. The results are shown in the graph plotted between arrival service requests for available bandwidth. The Fig. 2 shows the actual amount of bandwidth available for a particular network coverage area that each service provider needs to support its users' services. While the Fig. 3 show the number of admitted calls and dropped calls services by the networks under consideration. The graphical values represents only cumulative period values not the instance values. Here the graphical result from Fig. 2 shows that a fair proportion of resources are available for user services prior to the previous estimation based request to network service providers and they calculated the actual work load and distributed resources among themselves as per share of their user resources service requirement and the surplus is kept for new incoming requests if possible, which is roughly based on the previous estimation. If one of the Broadband, WLAN and WiMAX reaches its saturation leading to congestion then other two offer their bandwidth to it to share the load to keep off from saturation. But in normal network each network service provider is interested in its own network user and not willing to help others, but in coalition policy each participant network service provider is willing to offer its resources to the others in order to resolve the problem congestion in the network. The comparison between different services and proposed scheme resources is depicted in Fig. 4 and the resource allocation for user mobility pattern is represented in Fig. 5.

To evaluate the behavior of the proposed game theory model for load sharing under mobility of user devices we consider the mobility path from the point A to the point G in normal network coverage and the same path in coalition formed network coverage as represented in Fig. 1.

The user device call request admitted at the point A in coverage area c_1 and it moves to next coverage area c_2. Since at this place all three network servicing participants are in saturated region, and some call drop has already occurred here also as shown in embedded Fig. 1. Further almost no call drop occurs as the user further moves from B to C under coverage area c_2 to c_1 shown is Fig. 1. In the region around D the user again moves from c_1 to the new coverage area c_3 loosing services offered via WLAN. This results in the releases of bandwidth load on WLAN and this act makes WLAN services to get out from the congestion stage. Next, in this network location WiMAX and Broadband collectively share manual load suffers and at the same time when the user moves from D to E, i.e. form the coverage area c_3 to again c_1 he suffers no congestion and no call drops. But finally when he moves to F in the

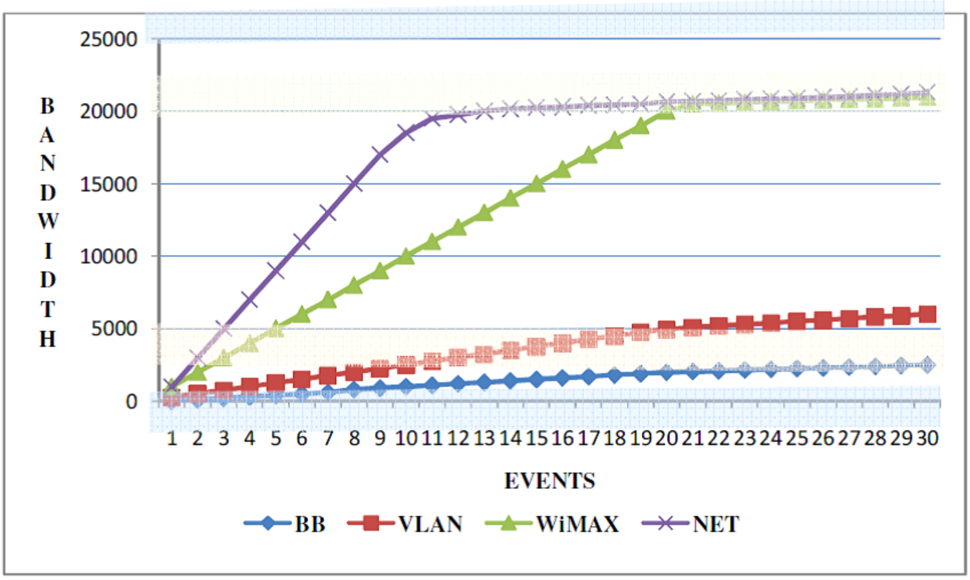

Fig. 2: Comparison between different services and the available resources.

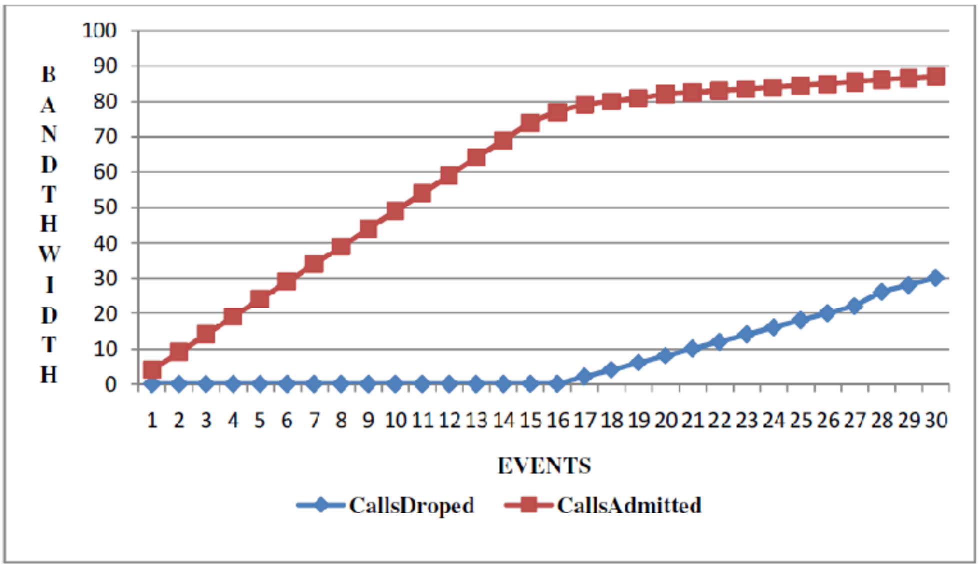

Fig. 3: Resource allocation for user mobility in geographical coverage area c_1.

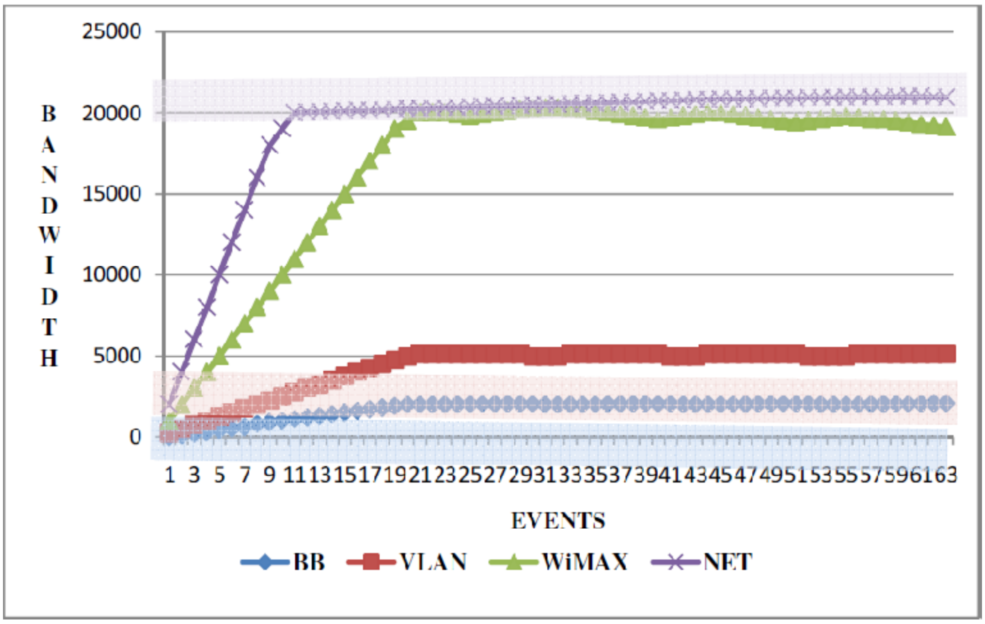

Fig. 4: Comparison between different services and proposed scheme resources.

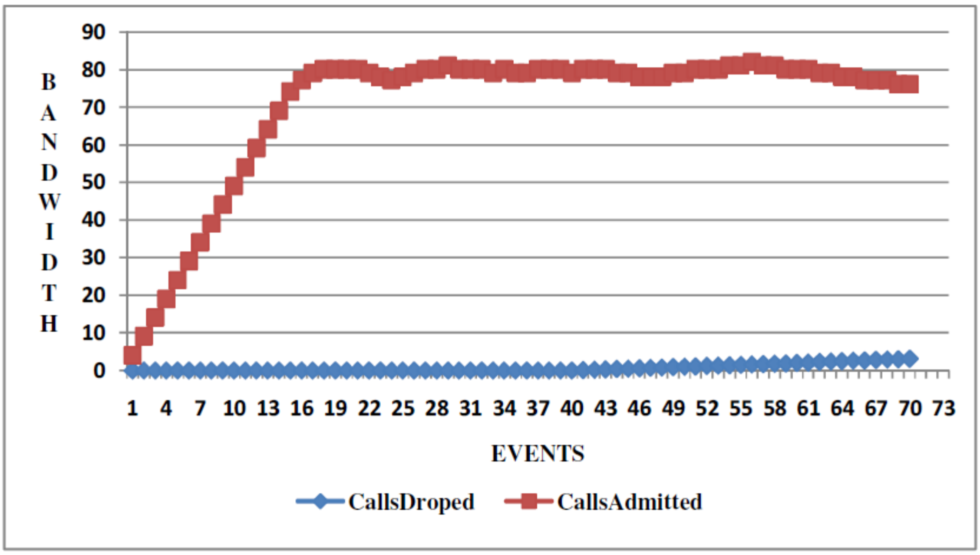

Fig. 5: Resource allocation for user mobility pattern.

coverage area c_4 moving far apart from the WiMAX coverage area, it results in the cases of call drops since, call drop only occurs at two moving location areas c_1 to c_2 and c_2 to c_4.
Finally, when he moves moves from F to G which means from the coverage region c_4 to c_8 under simple network if the network provider has some resources then he could be served. But when the user enters into a coalition policy enabled coverage area and roams about same path as he moved through previously, then there is no saturation and no congestion is found over the path as was found previously without the association policy. Furthermore the capacities of the network service providers are increased and their ability to bear more load stress during the peak hours is enhanced. The other benefit flowing out of this policy is that the network service providers, who form a coalition, dominate over their rivals within the places where they are acting under a coalition policy with their coalition partners having a more better status to bear the stress of user load and provide better services even with their having own weaker resources.

6 Conclusion

This paper presents a new concept based on game theory inspired from resource sharing that is based on cooperative game theory where all participant network subscribers cooperate with each other to share their resources for user requests and provide their users with versatile services. This paper demonstrates a perfect cooperative nature in which the participant first donates his excess resources to coalition and then afterwards they utilize their own share of resources. These acts make the coalition formation more stable and inspire others to migrate towards cooperation for better services to use. Inspired from the perfect cooperative policy we can develop resources sharing, resource handover, new call admission, handover mechanism, etc. Our simulation results show that the smart resource sharing and management technique described here leads a better performance than any of the existing cooperative games approach theories.

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References

[1] Luo, J., Mukerjee, R., Dillinger, M., Mohyeldin, E. and Schulz, E. (2003). Investigation of radio resource scheduling in WLANs coupled with 3*g* cellular network, *IEEE Comm. Magazine*, 41(6), 108–115.

[2] Pries, R., Mäder, A. and Staehle, D. (2006). A network architecture for a policy based handover across heterogeneous networks, in *Proc. OPNETWORK 2006*, 244–252, Washington D.C., USA, Aug 2006.

[3] Song, W., Zhuang, W. and Cheng, Y. (2007). Load balancing for cellular/WLAN integrated networks, *IEEE Network*, 21(1), 27–33.

[4] Taha, A.E.M., Hassanein, H.S. and Mouftah, H.T. (2008). Vertical handoffs as a radio resource management tool, *Comput. Commun.*, 31(5), 950–961.

[5] Niebert, N., Schieder, A., Abramowicz, H., Malmgren, G., Sachs, J., Horn, U., Prehofer, C. and Karl, H. (2004). Ambient networks: an architecture for communication networks beyond 3g, *IEEE Wireless Communication*, 11(2), 14- 22, EU.

[6] Dimou, K., Agero, R., Bortnik, M., Karimi, R., Koudouridis, G., Kaminski, S., Lederer, H. and Sachs, J. (2005). Generic link layer: a solution for multi-radio transmission diversity in communication networks beyond 3g, in *Proc. IEEE* 62^{nd} *Vehicular Technology Conf.*, Vol. 3, 1672- 1676, Dallas, TX, USA.

[7] Bazzi, A., Pasolini, G. and Andrisano, O. (2008). Multi radio resource management: parallel transmission for higher throughput?, *EURASIP Journal on Advances in Signal Processing (JASP)*, Special issue entitled "Wireless Cooperative Networks", volume 2008, Article ID 763264, 9 pages, June 2008. DOI: 10.1155/2008/763264.

[8] Niyato, D. and Hossain, E. (2006). A cooperative game framework for bandwidth allocation in 4*g* heterogeneous wireless networks, *Proc. IEEE International Conference on Communications ICC '06*, 9, 4357–4362.

[9] Suliman, I.M., Pomalaza-Rez, C., Lehtomki, J. and Oppermann, I. () . Radio resource allocation in heterogeneous wireless networks using cooperative games, *Proc. Nordic Radio Symposium 2004 / Finnish Wireless Communications Workshop (NRS/FWCW)*, Oulu, Finland, 16 18 August 2004.

[10] Das, S., Lin, H. and Chatterjee, M. (2004). An econometric model for resource management in competitive wireless data networks, *IEEE Network*, 18(6), 20–26.

[11] Niyato, D. and Hossain, E. (2006). Bandwidth allocation in 4*g* heterogeneous wireless access networks: a noncooperative game theoretical approach, *Proc. IEEE Global Telecom. Conf. GLOBECOM '06*, Vol. 11, 1–5, 27 San Francisco, California, 27 Nov.- 1 Dec. 2006.

[12] Halder, N. and Song, J.B. (2007). Game theoretical analysis of radio resource management in wireless networks: a non-cooperative game approach of power control, *IJCSNS International Journal of Computer Science and Network Security*, 7(6), 184–192.

[13] Badia, L., Taddia, C., Mazzini, G. and Zorzi, M. (2005). Multiradio resource allocation strategies for heterogeneous wireless networks, *Proc. Wireless Personal Multimedia Communications Conference (WPMC '05)*, Aalborg, Denmark, 18–25, September, 2005.

[14] Pandremmenou, K., Kondi, L.P. and Parsopoulos, K.E. (2012). Kalai–Smorodinsky bargaining solution for optimal resource allocation over wireless DS–CDMA visual sensor networks, *Proc. of SPIE-IS& T*, Vol. 8305 83050T, 1–11, San Francisco, USA, January 2012. Contents available at http://proceedings.spiedigitallibrary.org/on04/21/2013, Terms of Use: http://spiedl.org/terms.

[15] Myerson, R.B. (1991). Game Theory, Analysis of Conflict, Harvard University Press, Cambridge, MA, USA.

[16] Basar T. and Olsder, G.J. (1999). Dynamic Noncooperative Game Theory, SIAM Series in Classics in Applied Mathematics, Philadelphia, PA, USA.

[17] Owen, G. (1995). Game Theory, Third edition, Academic Press, London, UK.

[18] Han, Z. and Liu, K.J. (2008). Resource allocation for wireless networks: basics, techniques, and applications, Cambridge University Press, New York, USA.

[19] Alpçan and Basar, T. (2005). A globally stable adaptive congestion control scheme for internet-style networks with delay, *IEEE/ACM Trans. On Networking*, 13, 1261–1274.

[20] La, R.J. and Anantharam, V. (2004). A game-theoretic look at the Gaussian multiaccess channel, *Proc. of the DIMACS Workshop on Network Information Theory, New Jersey, NY, USA, Mar. 2003*, Volume 66 (2004), 87–106.

[21] Mathur, S., Sankaranarayanan, L. and Mandayam, N. (2008). Coalitions in cooperative wireless networks, *IEEE J. Select. Areas Commun.*, 26, 1104–1115.

[22] Stackelberg, H. von (1952). The Theory of the Market Economy, Oxford University Press, Oxford.

[23] Havinga, P.J.M., Smit, G.J.M., Vognild, L.k. and Wu, G. (2001). The SMART project: exploiting the heterogeneous mobile world, *Proceedings of the* 2^{nd} *International Conference on Internet Computing IC'2001 Las Vegas, Nevada, USA, June 25–28, 2001.*, 346–352.

[24] Jain, R. and Varshney, U. (2002). Supporting quality of service in multiple heterogeneous wireless networks, *Proceedings of the IEEE IVehicular Technology Conference Birmingham, AL, USA, 2002*, 952–956. DOI: 10.1109/VTC.2002.1002629

[25] Schill, A., Kühn, S. and Breiter, F. (1997). Resource reservation in advance in heterogeneous networks with partial ATM infrastructures, *Proceedings of the IEEE INFOCOM Kobe, Japan, April 7–12, 1997*, 612–619.

[26] Kalai, E. and Smorodinsky, M. (1975). Other solutions to Nash's bargaining problem, *Econometrica*, 43(3), 513–518.

[27] Conley, J.P. and Wilkie, S. (1991). The bargaining problem without convexity: extending the Egalitarian and Kalai–Smorodinsky solutions, *Economic Lett.*, 36, 365–369.

[28] Khan, M.A., Truong, C., Geithner, T., Sivrikaya, F. and Albayrak, S. (2008). Network level cooperation for resource allocation in future wireless networks, *Wireless Days, 2008. WD '08, 1st IFIP*, 1–5.

[29] Yang, B., Shen, Y., Feng, G. and Guan, X. (2009). Fair resource allocation using bargaining over OFDMA relay networks, *Proceedings of the* 48$^{\text{th}}$ *IEEE Conference on Decision and Control (CDC)*, 585–590, Shanghai, China, 15–18 Dec, 2009.

[30] Chen, J. and Swindlehurst, A.L. (2009). Downlink resource allocation for multi–user MIMO–OFDMA systems: The Kalai–Smorodinsky bargaining approach, *3rd IEEE International Workshop on Computational Advances in Multi–Sensor Adaptive Processing (CAMSAP)*, Aruba, Dutch Antilles, Netherlands, Dec. 2009, 380–383. DOI: 10.1109/CAMSAP.2009.5413250

[31] Park, H. and Schaar, M. van der, (2010). Fairness strategies for wireless resource allocation among autonomous multimedia users, *IEEE Transactions on Circuits and Systems for Video Technology*, 20, 297 –309.

[32] Park, H. and Schaar, M.van der (2007). Fairness strategies for multi–user multimedia applications in competitive environments using the Kalai–Smorodinsky bargaining solution, *Proc. IEEE International Conference on Acoustics, Speech and Signal Processing*,Honolulu, Hawaii, USA, April 15-20, 2007, 713–716.

[33] Mastronarde, N. and Schaar, M.van der (2008). A bargaining theoretic approach to quality–fair system resource allocation for multiple decoding tasks, *IEEE Transactions on Circuits and Systems for Video Technology*, 18, 453–466.

[34] Canzian, L., Badia, L. and Zorzi, M. (2013). Promoting cooperation in wireless relay networks through Stackelberg dynamic scheduling, *IEEE Transactions on Communications*, 61(2), 700- 711. DOI: 10.1109/TCOMM.2012.120512.110654