Cumhuriyet Üniversitesi Fen Fakültesi
Fen Bilimleri Dergisi (CFD), Cilt:36, No: 3 Özel Sayı (2015)
ISSN: 1300-1949

Cumhuriyet University Faculty of Science
Science Journal (CSJ), Vol. 36, No: 3 Special Issue (2015)
ISSN: 1300-1949

Reputation Based Cooperation Between Network Operators in the Heterogeneous Wireless Environments

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Received: 01.02.2015; Accepted: 05.05.2015

Abstract. Todays, the cooperation between operators to provide high quality service has been taken into consideration due to increasing demand for high-rate service and challenges such as costs for deployment of equipment by the operators,. Therefore, in current paper, cooperation among operators to for sharing resources is studied according to utility obtained from service provider in terms of quality of service, financial cost and energy consumption features for different preferences considering reputation concept. For payoff allocation is done in the cases that a pool of operators exists based on reputation aware weighted Shapley value power index. It is shown that the operators get payoff related to required service preferences. Also, it is shown that the operators with higher reputation can earn more payoff which this encourages them to increase their service quality.

Keywords: Payoff, Operator, Weighted Value Shapley, Reputation

1. INTRODUCTION

Nowadays, by development of next generation networks and equipping the mobile devices with various interfaces, there is a high demand for various services with high rate. In this environment integration of different networks helps to support service requirements of users anywhere, anytime [1-3]. It can improve the users' experience concerning different applications and user support requirements. On the other hand, it is not economical for operators to deploy new equipment while providing unlimited resources, by themselves. To deal with this issue, cooperation between operators for resource sharing can increase the network benefits, efficiency and support various user demand [4]. As a result of cooperation, extending zone coverage of delivery service to users, load balancing between different networks, increasing network utilization and user satisfaction can be obtained.

In recent years different research studies have been done to deal with network integration and cooperation between operators in the next generation networks. Problem of resource allocation as well as using excess bandwidth of network operators in the cooperative situation is presented in [5] as bargaining game. Auntiniou et al. [6] modeled cooperation among operators on a common service platform by using a voting game for cases that there is not enough resource for satisfying service requirements. In Daidalos project [8] communication infrastructure for developing NGN for all-IP network is deployed to deliver composite service to mobile users.

Authors in [7] modeled bandwidth allocation among users in the heterogeneous environment by using bankruptcy game as N-person cooperative game. In [9], cooperation is extended and load balancing between operators is studied. Chang and Chen [10] used roaming rate as incentive for collaboration among operators to act for spectrum sharing scheme. The game is modeled as market model and its goal is to find optimum roaming price in order to maximize the sum of profit functions of all cooperating operators.

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Special Issue: The Second National Conference on Applied Research in Science and Technology

In this paper, cooperation between independent operators in the integrated environment is explored. They can share their resources to support required service S of one NGN administrator such as an MVNO (Which can use the aggregated operators' bandwidth) for different service preferences. In this regards, power index weighted Shapley value is used for payoff allocation while the different values of reputation is analyzed by numerical results.

The rest of paper is organized as follows: in the next section, the cooperative resource sharing as pool of resource is studied by using weighted Shapley value power index based operators' reputation. Numerical results are proposed in section III. Finally, in section IV, a conclusion is presented.

2. SYSTEM MODEL

The assumed structure includes various access networks owning different administrative authority and controlled by different operators in a heterogeneous environment. In some cases that the MVO (Mobile virtual network) or NGN admin may request a large bandwidth, the operators can cooperate with each other by sharing unused resources to provide service to a great number of users. The cooperation should support service requirements of user according to their preferences.

It is considered that there is a common pool which the operators share their resources with others, the power indexes method Shapley Value method as a known method of power indexes [11] is used. Weighted Shapley value (WSV) is used to payoff distribution among the operators. We have employed the Weighted Value Shapley as a type of Shapley value for payoff distribution among the operators considering the effect of reputation which indicates how much the administrating operator is satisfied by cooperating operators.

To improve delivered utility to users, reputation concept is considered for operators participating in the formed coalition. By considering reputation factor, based on the history of the delivered services to the users, the operators including formed coalitions will be prioritized and therefore, a better service quality can be provided. This will encourage the operators to try to bring their reputation to the minimum threshold level. The level of reputation is considered in the sum of payoff distributed to these operators. As a result, operators try to improve their reputation in order to increase their payoff share.

3. GAME MODEL

Here, we have applied the cooperative game in characteristic form to formulate the resource allocation problems in a heterogeneous wireless multi-operator network structure. As mentioned previously, the operators cooperate with each other in order to provide service *S* (which needs minimum and maximum bandwidths of u_{min} and u_{max}) for the administrating operator. The formed grand coalition *T* includes a set of operators in game $G(N,\upsilon)$ by $N=\{1,2,...,n\}$. For the grand coalition *T*, $\upsilon(T)$ represents the overall value of the coalition, which is divided between its members. For simplification, $\upsilon(i)$ is used instead of $\upsilon(\{i\})$, and it characterizes the value of the stand-alone coalition of operator *I* and $\upsilon(\phi)=0$. Based on the administrator's criteria, characteristic function $\upsilon(S)$ is used for coalition formation among operators to provide service *S* for administrator's users.

Characteristic function $\upsilon(S)$ is defined as equation (1) for formed coalitions among operators to provide service *S* for the administrator's users to satisfy their needs. As shown in the equation, if the formed coalition has not minimum utility u_{min} , its coalition value is zero and this coalition cannot form.

$$\upsilon(S)=\begin{cases}1 & u>u_{max}\\ u & u_{min}<u<u_{max}\\ 0 & u<u_{min}\end{cases}$$

$$\begin{aligned}&s.t:\\ &a_1)\ \sum_i b_i > B_{min} \quad , \quad a_2)\ \overline{QoS}_{attributes} > min_{\mathrm{Req}} \qquad (1)\\ &a_3)\ \overline{Power} < max_{req}\\ &a_4)\ \overline{Cost} < max_{req}\end{aligned}$$

Where,

$$u = (f_{\mathrm{q}} - k.\, f_c)^{w1} \,.\, f_e^{\,w_2} \qquad (2)$$

Function f_{q} is the utility of QoS parameters related to the class of application (e.g. Telephony, video, file transfer). f_{c} is monetary cost and f_{e} is average energy consumption in relation to the formed coalition S. Utility function u is an increasing function for f_{q} and f_{e} .

4. PAYOFF ALLOCATION USING WSV

For payoff allocation, it is considered there is a pool of resources belonging to independent operators. In this section weighted Shapley value method related to reputation is used to devide payoff. The operators play the coalitional game G(N, v, λ), which N denotes the grand coalition of operators, v is the characteristic function and $\lambda \in R^n_{++}$ are the weight vectors of each operator. For game $v \in G^n$ and sub-games (T, v), $\forall T \subseteq N$; Potential Function (P) is defined in relation to weight vectors of operator i as follows:

$$\sum_{i\in T} \lambda_i \,[\mathrm{P}(T,\nu,\lambda) - \mathrm{P}(T-\{i\},\nu,\lambda)] = \nu(T), \forall T \subseteq N \qquad (3)$$

$$\mathrm{P}(\varphi(\nu,\lambda) = 0 \qquad (4)$$

With the summation of relation (3), and by considering $\lambda(T)=\sum_{i\in T}\lambda_i$, the recursion formula can be obtained as follows:

$$\mathrm{P}(T,\nu,\lambda) = \frac{1}{\lambda(T)}[\nu\nu(T+\sum_{i\in T}\lambda_i\ \mathrm{P}(T-\{i\},\nu,\lambda)] \qquad (5)$$

Based on the potential function (P), the Weighted Value Shapley of player i in a coalitional game can be obtained as Eq. (6):

$$\mathrm{WSH}_i(N,\nu,\lambda) = \lambda_i \mathrm{P}(T,\nu,\lambda) - \mathrm{P}(N-\{i\},\nu,\lambda)], \forall i \subseteq N \qquad (6)$$

In our case, the weights λ are determined based on the reputations of players. Consequently, since the payoffs that are allocated to players are based on reputation, the players try to increase their reputation. The weights λ for players are defined by Eq. 7 as follows:

$$\lambda_i = \frac{Rep_i}{\sum_{j1:N} Rep_j} \tag{7}$$

where Rep_i is reputation score of operator ***i***.

Reputation-based mechanisms have been applied frequently in wireless network environments, especially in Ad-Hoc structures and Peer-Peer networks [12]. In our proposed payoff allocation method, reputation is related to past action of operators, used in coalition formation between operators and payoff allocation. As seen in equation (7), the obtained payoff for participating operators is divided based on the reputation of operators to encourage them to improve their reputation factor and as a result higher utility in providing service. Reputation score can be calculated from users' report according to their past experience by the reputation manager.

5. NUMERICAL RESULTS

In this section, pay off allocation for participating operators for resource sharing by using WSV is studied for different admin's preferences and considering constant reputations for the operators. In studied scenarios, 6 operators as players cooperate on pool of resources for providing service *S* are considered to meet the minimum requirements of service *S* for three set weights for user preferences (economic user, energy importance user and quality user). Each operator has available resources, average energy consumption per unit bandwidth and a service charge. The requirements of normalized bandwidth, reputation, cost and energy as characteristics for service *S* which are required by NGN administrator, are used in the simulations and presented in Table 1. The characteristics of each operator including the normalized available bandwidth, cost per unit bandwidth, average utilized energy and the reputation of each operator is shown in Table 2 for three different scenario sets.

The numerical results are presented in Table 3. In this case, the financial weight (K) and quality case (W_2) are considered 0.1 and 0.9 in equation (2), respectively. It is observed that with the increase in the importance of energy, obtained utility increases. Since the operator 1 has lower energy consumption and operators 5 and 6 have consumed the higher amount of energy, so the allocated payoff to operator 1 increases and the allocated payoff to Operator 5 and 6 decreases. This means that if one metric is important for the administrator, the operators with higher quality in that metrics can receive more payoff. Moreover, since operators 5 and 6 have larger bandwidths to share, they can participate in more Minimum Winning Coalitions (because the minimum aggregated bandwidth should be larger than the minimum bandwidth threshold) and gain a higher payoff compared to other operators. It is worth mentioning that, payoff distribution for operators should be in a manner that the participating operators receive minimum payoff when provisioning bandwidth in cooperation.

Table 1. Normalized Value for Service Requirements S.

Minimum Bandwidth	0.7
Maximum Bandwidth	1
Minimum Utility	0.7
Maximum Utility	0.8
Minimum Price	0
Maximum Price	10
Minimum Power Consumption	0
Maximum Power Consumption	10

Table 2. Different characteristics of operators.

	Reputation	Cost	Bandwidth	Energy
Set	(0.9 0.8 0.85 0.95 1 0.9)	(3 2 4 3 2 2.5)	(0.3 0.35 0.4 0.45 0.5 0.55)	(1 2 3 4 5 6)

Table 3. Normalized Operators' Payoff.

Energy Important (Weight w_1)	Operator 1	Operator 2	Operator 3	Operator 4	Operator 5	Operator 6
0.1	0.09	0.10	0.15	0.18	0.23	0.25
0.2	0.10	0.11	0.15	0.18	0.22	0.25
0.3	0.10	0.11	0.15	0.18	0.22	0.24
0.4	0.11	0.12	0.15	0.18	0.22	0.23
0.5	0.12	0.13	0.15	0.17	0.21	0.22
0.6	0.13	0.13	0.15	0.17	0.21	0.21
0.7	0.13	0.14	0.15	0.18	0.21	0.20
0.8	0.14	0.14	0.15	0.18	0.21	0.19
0.9	0.15	0.15	0.14	0.18	0.21	0.17

To investigate the effect of reputation on payoff allocation using the WSV, simulations have been performed 1000 times for random weights, random operator's characteristics. The obtained results for operators 1 and 4 with different reputation values changing from 0 to 1, independently, have been presented in Table 4. It has been observed that as a result of the increase in the reputation of operator 1, its allocated normalized payoff increases and with the reduction in the reputation of operator 4, its allocated payoff will be reduced. Thus, the operators can be motivated to increase their reputation. Because, if only a minimum threshold limit is considered for reputation, the operators will keep their reputation to threshold level; but in this way, the participating operators can be motivated to improve their reputation. The results also indicate that since only the reputations of operators 1 and 4 have changed and the reputations of other operators have remained the same, their payoffs haven't changed much.

6. CONCLUSION

In the next generation networks, the network performance and operators' revenue can be enhanced by sharing resources via cooperation among operators. In this case, the high demand will be supported and the cost of implementing communication equipments decreases. Therefore, in this paper, reputation aware payoff allocation when cooperation among operators based on pool of resources is investigated based on weighted value Shapley power index for different random service conditions. It is shown that the operators with lower reputation value earn less average payoff compared with operators with higher reputation. This behavior encourages operators to increase their reputation and improve quality of their provided service.

Table 4. Normalized Payoff allocation by Using Weighted Value Shapley vs. Reputation.

	Operators' Payoff					
Reputation Operator 1	**O_1**	**O_2**	**O_3**	**O_4**	**O_5**	**O_6**
0.1	0.0202	0.1937	0.1921	0.1854	0.2123	0.1963
0.2	0.0453	0.1949	0.1968	0.1697	0.2078	0.1855
0.3	0.0624	0.1946	0.1891	0.1507	0.2109	0.1922
0.4	0.0888	0.1979	0.1913	0.1238	0.2051	0.1932
0.5	0.1052	0.1949	0.1919	0.106	0.2071	0.195
0.6	0.1236	0.1955	0.1904	0.0838	0.2141	0.1926
0.7	0.1495	0.1937	0.1913	0.0635	0.2113	0.1908
0.8	0.1759	0.1895	0.1876	0.0421	0.2119	0.193
0.9	0.1896	0.1877	0.1932	0.0214	0.2118	0.1963

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