Incentive Mechanisms in non-cooperative wireless networks

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Abstract

Ad-hoc network is a collection of interconnected wireless devices. The network is a decentralized network (i.e.)operates without any central agents such has base stations and access points.The project considers the problem of streaming data and increasing the quality of service for the same. Main field game theory perspective is used for the user position setup.In this set up the nodes cooperate by sharing their diverse resources with other nodes in the network. However, in some scenarios some of these nodes may not be willing to participate, which could be either voluntary or involuntary in nature. This has been proved to significantly degrade the overall performance of the system. A broadcast communication between base to device interface and device to base interface is to achieve the same.

The main challenges in this problem is to first identify the non-cooperative nodes (which we would refer to them as selfish nodes) and avoid such behavior.To avoid this problem, the proposed work establishes a broadcast communication between base to device interface and device to base interface.

I. Keywords

Base to device interface, Device to device interface, Broadcast, Unicast, Game theoretic model.

II. introduction

The aggrandizement of the wireless networks has bought several number of wireless users in the recent years. This steady increase in the users in turn requires more data.The voracious data usage hampers the performance of these networks.Thus the cellular networks as well as the users are trying to incorporate different schemes in order to increase the efficiency of the internet connectivity and reduce the network congestion.The wireless technology plays a significant role in almost all domains.One such example includes streaming of data, which is taken as major concern in this project. The approach in this project is to increase the performance parameter of such streaming between the base and devices.

In general, the packets are transmitted between different devices to reach their destination. The challenges in this environment include providing incentives to the intermediate nodes to improve the efficiency of the network by contributing their resources. In this project we are reviewing this issue in a game-theoretic framework.

Game theory is used to model the user's interaction with conflicting/mutual interests in wireless communication networks. Users play games through which an optimal solution is found and equilibrium is achieved.To increase the cooperation between the nodes incentive schemes are used.Here a credit based approach is followed.In credit based schemes, a virtual currency is defined in the system which we will refer to them as transfers.The currencies are used for the trade between users for performing utilities. The positive transfer is one in which the agent is paid by the system and the negative transfer is a price paid by the agent. This provides an incentive for users to cooperate and relay information for one another.

A base to device interface has an expensive unicast communication but a cheaper broadcast communication. The transmission is done in two stages, base to device broadcast and device to device broadcast. Hence, this ensures that all the blocks of data is received by each individual user.This prevents re-transmission of data due to the loss of data blocks.

In section III-A we review the paper in [1] ”Bits and Coins: Supporting Collaborative Consumption of Mobile Internet” in details. In section III-B, we talk about [2] ”Incentivizing Sharing in Realtime D2D Streaming Networks: A Mean Field Game Perspective”. This is followed by IV which describes the problems in the above papers and provides solutions to overcome the problems.

III. RELATED WORK

A. Bits and Coins: Supporting Collaborative Consumption of Mobile Internet

The authors in [1] consider the Mobile user- provided networks (MUPN) in which mobile users are interconnected via device to device (D2D) connection. The users may also download or upload content from/to internet directly. The challenge is to provide successful services which depends on the fair play of the users in the network(resource sharing, internet access, battery energy).The authors have structured a cloud controlled the Mobile user- provided networks (MUPN) system which allows the users to establish packet forwarding policies with adaptive flow control. A centralized decision making process determines the amount of resources to be devoted by the individual users in the network.The incentive is provided in the form of a virtual currency - defined in the form of coins for the services done by the nodes; i.e., an intermediate node spends coins for the amount of information to be transmitted by others and later reimburse in exchange for sharing its resources with others.

A coalitional game consisting of all MUPN participants is played and a framework is constructed based on it.Here, the main motive is to constitute a single entity pursuing where in the aim is to achieve maximum aggregate utility of the network or similarly decrease the aggregate cost. On producing maximum cooperation among the users the performance of network is increased,the resiliency of the network is improved,system and individual utility of the users is maximized and added to this the affiliation on the external infrastructure is reduced.

A co-operative game consists of N players with a characteristic function suitable at all coalitions of players and generate cost accordingly $V : 2^{[N]} \rightarrow \mathbb{R}$ The problem in this environment is to determine the interest of all the users in the network to form a grand coalition rather than merely, fragmenting into separate subgroups. In game theoretic perspective, it means to this issue look for a non-empty core for the coalitional game of the users.

In this work the characteristic function , concave in nature , is defined which comprises both the energy consumption cost and the financial cost associated with the mobile data usage. It is observed that this function will introduce a non-empty core for the coalitional game formed by the users. However, the set of convex constraints including energy consumption of individual users is also taken into account by the formulated optimization problem as follows:

$$\max_{\boldsymbol{x},\boldsymbol{y}} \sum_{i \in \mathcal{N}} (V_i(\boldsymbol{x}_i, \boldsymbol{y}_i) - V_i^s)$$

Where $\mathcal{N}$ denotes the set of users, $V_i(.)$ indicates the payoff associated with user $i \in \mathcal{N}$ and V_i^s is the payoff user i achieves by operating individually subject to :

$$\sum_{j \in In(i)} \boldsymbol{x}_{ji}^{(n)} + \boldsymbol{y}_{ji}^{(n)} = \sum_{j \in Out(i)} \boldsymbol{x}_{ij}^{(n)} \;\; \forall i, n \in \mathcal{N}, i \neq n$$

$In(i)/Out(i)$ denotes the set of neighbors who either transmit message or receive message from the node i. Here $\boldsymbol{x}$ and $\boldsymbol{y}$ are represented as the data shared via device to device connection and Internet, respectively. Added to it the collaborative network sharing platform prototype is implemented with a OpenVSwitch (OVS) OpenFlow datapath for each device followed by the Linux HTB queueing. The proposed system in this paper is adaptive and with a robust solution and therefore proved to have minimal resource conception which doesn't affect the user's experience

B. Incentivizing sharing in realtime D2D streaming networks: A mean field game perspective

One of the key features investigated in [2] is the real time streaming of content for users which are in proximity of one another. To capture the real time essence of the model, they restrict the delay in streaming a piece of information to 2 frames. i.e. time is divided into frames, and frames are further subdivided into T time slots. Frame $k-2$ is the B2D interface the base station performs a RLC on the N chunks of information and unicasts some of the coded chunks to each device. For each user i, the number of received chunks during the B2D interface is denoted by $e_i[k]$. In frame $k-1$ during the D2D interface, users disseminate their information and if possible, the content is played out in frame k. During the Optimal allocation rule proposed in this paper, the users are partitioned into sets

$$\mathcal{S} = \{i \in \{1, ..., M\} : N - e_i[k] \leq T, e_i[k] + \sum_{j \neq i} e_j[k] \geq N\} \text{ and } \mathcal{S}^c$$

It is intuitive that users in $\mathcal{S}$ are able to play out the in frame k if they receive enough information during frame $k-1$.

IV. Proposed Work

The proposed work optimizes the power flow decisions based on a fixed known set of communication links among nodes, i.e., ϵ . A more sophisticated approach would be to optimize the network topology and update it at the end of each individual iteration. This may rather enhance the overall performance of ad-hoc wireless network significantly.

Generally, wireless ad hoc networks require special treatments due to their intrinsic characteristics such as limited memory and battery life. These treatments include finding the optimal power efficient network topologies which take into account the network limitations. The optimal topology should satisfy different objectives such as minimizing the maximum link length and at the same time maintaining the connectivity of the network and bounding the average node degree.

Several approaches have been proposed in the literature which result connected graphs with low weighted links. The main concern here is to make a topology robust to dynamic nature of mobile ad-hoc networks. Therefore, the connectivity of network should be ensured within all possible movements of the nodes. Authors in [2] have proved that Local Tree-based Reliable Topology (LTRT) is the most scalable and efficient algorithm for topology control of mobile ad-hoc networks. It is proven that LTRT guarantees k-edge connectivity while providing satisfactory performance as compared to its counterparts.

Moreover, a very recent work in mobile ad-hoc networks determines the optimal topology update interval for LTRT [2]. Generally, topology update algorithms assume a uniform update interval which is not a rational assumption in ever-changing mobile ad-hoc networks with unpredictable nodes behaviours. The proposed method repeatedly updates the update interval of the topology while ensuring a certain level of connectivity for a given node speed. The results presented in this work demonstrate significant improvement in dynamic LTRT algorithm compared to LTRT with fixed update interval.

We believe that combining an optimal topology update algorithm with the proposed collaborative architecture in this work will improve the overall performance of the network. This will further be improved by applying the algorithm in [2] for determining the optimal update interval and not just relying on a fixed interval as suggested in the standard LTRT.

On studying the papers [1]Bits and Coins: Supporting Collaborative Consumption of Mobile Internet and [2] Incentivizing sharing in realtime D2D streaming networks: A mean field game perspective , the shortcomings in the papers are observed. The identified problems are taken into consideration and solutions are being discussed below.

A. *Problem 1 and Solution*

One of the open problems in the context [2] is the choice of T. A careful choice of T is crucial to provide the users with sufficient information from the base station yet does not rely heavily on the B2D link. As T increases, larger amount of information is transmitted during the B2D phase to users and also more number of D2D transmissions take place. However we are interested in finding the minimum amount of T. Another idea can be to consider the case where number of time slots during the D2D transmission be different from the number of time slots in the B2D phase and find the optimal such specification.

B. *Problem 2 and Solution*

Another assumption in this channel model is that the B2D interface consist of multiple unicast transmission. To be more specific, during the T time slots for each M number of users, it requires TM unicast transmission. Our conjecture is that the performance (bandwidth, delay) of the network can be improved by asking the base station to broadcast the information. i.e. only broadcast the N chunks of information to all users *without* performing a random linear coding beforehand. With the assumption that number of users M is large, the probability that a chunk goes missing in *all* users is small. As a result, with proper dissemination of information during the D2D phase, users can recover all N pieces of information. In the D2D phase, in order to reduce the number of transmission and delay it is beneficial to use a network coding in the physical layer of the network and transmit the coded information to other devices. Broadcasting the information from the base station to the devices however may not always be applicable due to use of different carriers among different users. In this scenario base station can multicast the information to users within the same carrier during the B2D interface.

C. Problem 3 and Solution

Apart from the problem that is considered in [cite incentivizing], there exists other scenarios that users are not interested in the same content but wish to relay information through the intermediate nodes. As it was discussed in [cite capacity scaling law], the are $M/2$ pairs of users in a plane unit area and they wish to communicate with each other. Using a long range transmission between pairs causes a large amount of interference to the other users. An alternative to this scheme is the use of multiple hop relaying scheme which uses multiple short range transmission and the information is relayed through the intermediate nodes. In the existing literature on capacity scaling laws, it is mostly assumed that users cooperate with each other and selfish behavior is not experienced in the system. However as we know, this is an unrealistic assumption and an approach as in [cite incentivizing] using MFG can be beneficial.

We also have to note that relaying the information also consumes energy. Energy and battery life specially play a great role in mobile devices in which their resources are limited. Hence as another adjustment to [cite incentivizing], energy consumption during the D2D interface must be taken into account. In order to do so, we define the new value function as follows:

$$v_i(\mathbf{a}, \theta_i) = c((d_i + \eta - \chi_i((a, \theta_i))^+ + r_i)$$

where

- c is a cost function that is convex and monotonically increasing.
- d_i is the deficit for user i during the B2D transmission.
- η is the delivery ratio.
- $\chi_i(\mathbf{a}, \theta_i) = 1$ only if with allocation $\mathbf{a}$, user i is able to decode the N chunks of information.
- r_i is the percentage of battery of user i used in order to relay information for other devices.

V. Conclusion

The aforementioned papers , figures out different incentive schemes to enhance the performance of the mobile user provided network where the former applies a coalitional and the latter uses mean field game theoretic approach. Both assume a unicast connection between the base and the device and hence concentrates on the device to device connection. However they have different perspectives toward the problem accounting varied constraints such as energy [1] and delay[2].In this project, the base station broadcast is implemented followed by the device to device broadcast.The incentive scheme(transfers) also takes energy into account unlike in [2].Since data is received from both the base and the devices re-transmission of data is not required which the loss and delay in streaming the data.

References

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