International Journal of Innovative Research in Computer Science and Engineering (IJIRCSE)
www.ioirp.com ISSN: 2394-6364, Volume – 2, Issue – 2. February 2016

Efficient Resource Allocations for Spectrum Leasing In Cognitive Radio Networks

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Abstract

Resource allocation problem for spectrum leasing in Cooperative Cognitive Radio network (CCRN). More specifically, to determine when it is beneficial for a Primary User (PU) to lease its unused spectrum portion to Secondary User (SU) and how much of Primary User's resource is optimum to be leased. The Secondary User is supposed to cooperate with Primary Users by relaying the Primary User's signals, in return. Besides, the optimum allocated cooperating power of Secondary User to relay each Primary User's signals is determined. To lease to the secondary network in exchange, the Access Point (AP) of the secondary network offloads data traffic for the primary (cellular) users in its range. To enable spectrum leasing, the Access Point (AP) of the secondary network is equipped with an auxiliary radio that can be tuned to the frequency of the leased channel (licensed spectrum). The optimal resource allocation that ensures efficiency as well as fairness among users is provided by the Nash solution. Users achieve higher throughput via the proposed Cooperative Cognitive Radio Network (CCRN) framework.

Keywords-Cognitive Radio Networks, Co-operative Cognitive Radio Network, Resource Allocation, Primary User, Secondary User, Spectrum Sharing.

I. Introduction

However, the current fixed spectrum allocation of Federal Communications Commission (FCC) cannot utilize spectrum resource efficiently. One of the promising approaches to increase spectrum efficiency is cognitive radio technology, which enables secondary users (SUs) to sense spectrum and opportunistically access idle spectrum bands owned by primary users (PUs) [1],[2]. Cooperative cognitive radio network (CCRN) [3], [4] is a new paradigm in cognitive radio networks. Different from traditional cognitive radio networks in [5], [6], by integrating cooperative communications, SUs in a CCRN could still gain transmission opportunities even when PUs are active to transmit.

The electromagnetic radio spectrum is limited and valuable resource, which is tightly managed by governments. Recent reports shown significantly unbalanced usage of spectrum: some frequency bands are largely unoccupied most of the time; some other frequency bands are only partially occupied; the remaining frequency bands are heavily used [7]. Spectrum utilization can be improved significantly by allowing secondary users to access spectrum holes unoccupied by primary users. Cognitive radio [8] has been proposed as the means for secondary users to promote the efficient utilization of the spectrum by exploiting the existence of spectrum holes.

A. Cognitive Radio:

Cognitive Radio(CR) is an intelligent radio that sense the environment it can be programmed and configured dynamically .Such a Radio is an automatically detects available spectrum ,then accordingly changes its transmission and reception parameter to allow one or more concurrent wireless communication in a primary user spectrum band at one location.

While static resource allocation has many advantages, it can lead to very inefficient use of the spectrum, and many studies have shown that many allocated frequency bands are significantly underutilized. One reason is that spectrum use is often localized (e.g., around airports, etc.), leaving many frequency bands unused in significant parts of the country. Since most easily usable spectrum bands have been allocated, creating a future Directions in Cognitive Radio Network.

B. Primary network

Primary users

Primary users have the license to operate in certain spectrum bands. The user which has an exclusive right to a certain spectrum band.In other words, the license holders.No need to be aware of cognitive users.No additional functionalities or modifications needed**.**LTE User is a good neighbour to wi-fi.LTE user detect and decode wi-fi signal.

Primary base station controls the access of primary users to spectrum.

C. Secondary network

Secondary users

Secondary users have no licensed bands assigned to them.Cognitive-radio enabled users. Lower priority than Pus.Operator solely in unlicensed spectrum without licensed channel.

Secondary base-station:

A fixed infrastructure component with cognitive radio capabilities and provides single hop connection to secondary users.

Spectrum broker:

Scheduling server shares the spectrum resources between different cognitive radio networks.

D. Goal of Licensed User

To Protect Primary User

To increase the cognitive radio network throughput

E. Resource Allocation

Linear Transmission

Perfect Synchronization

Flat Fading Channels

F. CRN Design Issues

Multi User Communication

Multiple and Random Access

Cellular system design

G. CR Advantages

Improved Spectrum Sensing: By using cognitive radio networks, it is possible to gain significant advantages in terms of spectrum sensing.

Improved coverage: By setting up cognitive radio network, it is possible to relay data from one node to the next. In this way power levels can be reduced and performance maintained.

H. Co-operative Cognitive Radio Networks

In cooperative cognitive radio networks (CCRNs), through cooperating with primary transmissions, secondary users (SUs) could access the spectrum resource when primary users (PUs) are transmitting. The existing schemes in CCRNs allocate the spectrum resource only to the cooperative relay SU. However, this may lead to the waste of spectrum resource, especially when the relay SU has light traffic load or poor channel condition. To better utilize the spectrum among all SUs in a secondary network, to design a spectrum resource utilization maximization scheme with joint consideration of relay selection and spectrum scheduling problems. With the goal to maximize the throughput of the secondary network, our scheme allocates spectrum among all SUs according to the diversity of secondary traffic load and the channel conditions.

I. Cognitive Radio performs the following functions:

1. Spectrum sensing: Cognitive radio user has the ability to sense the unused spectrum at any time and location.

2. Spectrum Decision: Spectrum decision is the ability of a cognitive radio (CR) to select the best available spectrum band to satisfy secondary users' (SUs') quality of service (QoS) requirements, without causing harmful interference to licensed or primary users (PUs). Each CR performs spectrum sensing to identify the available spectrum bands and the spectrum decision process selects from these available bands for opportunistic use. Spectrum decision constitutes an important topic which has not been adequately explored in CR research. Spectrum decision involves spectrum characterization, spectrum selection and CR reconfiguration functions. After the available spectrum has been identified, the first step is to characterize it based not only on the current radio environment conditions, but also on the PU activities. The second step involves spectrum selection, whereby the most appropriate spectrum band is selected to satisfy SUs' QoS requirements. Finally, the CR should be able to reconfigure its transmission parameters to allow communication on the selected band. Key to spectrum characterization is PU activity modelling, which is commonly based on historical data to provide the means for predicting future traffic patterns in a given spectrum band. This paper provides an up-to-date survey of spectrum decision in CR networks (CRNs) and addresses issues of spectrum characterization (including PU activity modelling), spectrum selection and CR reconfiguration.

3. Spectrum Sharing: Spectrum sharing cognitive radio networks allows cognitive radio users to share the spectrum of the licensed-band users. However, the cognitive radio users have to restrict their transmit power so that the interference caused to the licensed-band users is kept below a certain threshold.

4. Spectrum mobility: Process by which a Cognitive-Radio user changes its frequency of operation. Cognitive-Radio networks aim to use the spectrum in a dynamic manner by allowing radio terminals to operate in the best available frequency band, maintaining seamless communication requirements during transitions to better spectrum.

II. Existing System

Efficient spectrum sharing is very important in the cognitive radio networks. To enhance the utilization of the frequency spectrum the cognitive radio should follow optimal spectrum sharing policies. Currently, dynamic spectrum sharing is being used in the Cognitive Radio networks. Spectrum sharing is the critical issue among all the functional blocks of the cognitive radio, so it is necessary to know about the spectrum sharing techniques for efficient use of the frequency spectrum. Spectrum sharing and access are important issues facing opportunistic communication in multiuser Cognitive Radio systems. Because of the presence of user priority (primary and secondary), they pose unique design challenges that are not faced in conventional wireless systems. In an environment with multiple this tradeoff and identify the optimal amount of spectrum sharing that maximizes the total primary and secondary users, the tradeoff between sum throughput maximization and primary user interference minimization is a result of the well known interplay between regulation and autonomy. In scenarios with perfect primary user sensing and transmissions at the channel capacity, we characterize system throughput. Observe that the optimal fraction of primary users is equal to the duty cycle of the data traffic. A uniform random distribution is used here, where CW is the current contention window size. The following equation is used to calculate the

Backoff time (BO): BO = (Rand () MOD CW)* aSlotTime (1).

The backoff procedure is performed then, by putting the node on a waiting period of length BO. Using carrier sense mechanism, the activity of the medium is sensed at every time slot. If the medium is found to be idle then the backoff period is decremented by one time slot.

Backoff time (BO) new = (BO) old - aSlotTime (2)

III. Proposed System

CCRN framework for primary network that supports any current cellular standard, such as LTE, and an IEEE 802.11multi-rate WLAN based secondary network. The secondary AP, all users (either primary or secondary) employ an IEEE 802.11 based channel contention mechanism. Both the AP and the BS are connected to the Internet over wire line channel, as is common in the present-day deployments. To lease to the secondary network in exchange, the AP of the secondary network offloads data traffic for the primary (cellular) users in its range. To enable spectrum leasing, the AP of the secondary network is equipped with an auxiliary radio that can be tuned to the frequency of the leased channel (licensed spectrum).All the user equipments (primary and secondary) are also equipped with radios that can be tuned to the unlicensed frequency as well as the leased channel and support dual-mode (Ex. Wi-Fi þ Cellular)

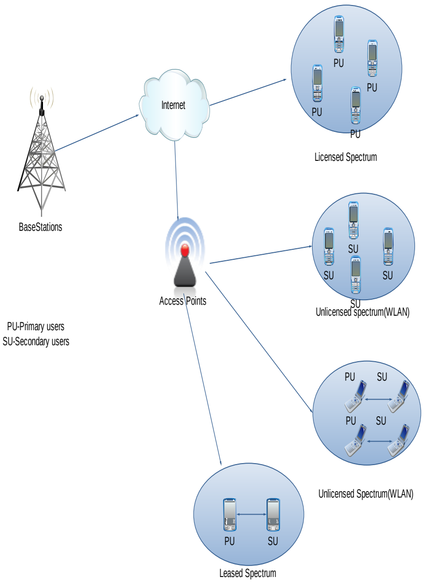

Fig1. System Architecture

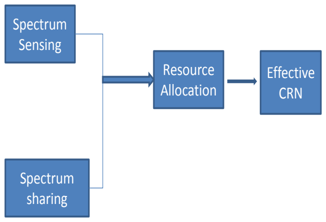

Fig2. Proposed System

A. Distributed and centralized MAC access

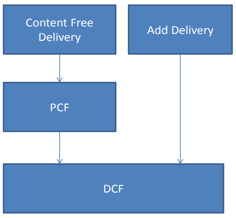

Fig3.MAC Coordination Function

1. Distributed Coordination Function (DCF)
2. Point Coordination Function (PCF)

Access to the wireless medium is controlled by coordination functions. Ethernet-like CSMA/CA access is provided by the distributed coordination function (DCF). If contention-free service is required, it can be provided by the point coordination function (PCF), which is built on top of the DCF. Contention-free services are provided only in infrastructure networks.

A. Distributed Coordination Function (DCF)

DCF requires transmitting listen for the channel status for DIFS interval. If the channel is found busy during the DIFS interval, the station defers its transmission. Share the medium between multiple stations

Rely on CSMA/CA and optional 802.11 RTS/CTS. The DCF is the basis of the standard CSMA/CA access mechanism. Like Ethernet, it first checks to see that the radio link is clear before transmitting. To avoid collisions, stations use a random back off after each frame, with the first transmitter seizing the channel. In some circumstances, the DCF may use the CTS/RTS clearing technique to further reduce the possibility of collisions. Most traffic uses the DCF, which provides a standard Ethernet-like contention-based service. The DCF allows multiple independent stations to interact without central control, and thus may be used in either IBSS networks or in infrastructure networks.

DCF Limitation

- When many collisions occur, the available bandwidth will be lower
- No notion of high or low priority traffic
- A station may keep the medium
  If the station has a lower bitrates, all other stations will suffer from that
- No QoS guarantees
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- No QoS guarantees

DCF uses RTS-CTS exchange to avoid hidden terminal problem. Any nodes overhearing CTS cannot transmit for the duration of the transfer. Uses ACK to provide reliability, Collision avoidance. Back off intervals used to reduce collision probability.

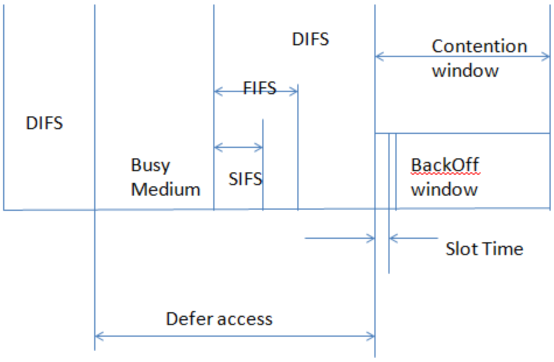

Fig4. How DCF works

Inter frame Spacing

Varying inter frame spacings create different priority levels for different types of traffic. The high-priority traffic doesn't have to wait as long after the medium has become idle. To assist with interoperability between different data rates, the inter frame space is a fixed amount of time, independent of the transmission speed.

- Short inter frame space (SIFS)

The SIFS is used for the highest-priority transmissions, such as RTS/CTS frames and positive acknowledgments.

- PCF inter frame space (PIFS)

The PIFS is used by the PCF during contention-free operation. Stations with data to transmit in the contention-free period can transmit after the PIFS has elapsed and preempt any contention-based traffic.

- DCF inter frame space (DIFS)

The DIFS is the minimum medium idle time for contention-based services. Stations may have immediate access to the medium if it has been free for a period longer than the DIFS.

DIFS=SIFS+ (2*SLOT TIME)

SIFS=Short Inter frame Space

- Extended inter frame space (EIFS)

It is not a fixed interval. It is used only when there is an error in frame transmission.

B.Point Distribution Function

Available only in "infrastructure" mode Optional mode, only very few APs or Wi-Fi adapters actually implement it. Beacon frame, Contention Period, and Contention Free Period.

C. Binary Exponential

Backoff Exponential Backoff is an algorithm that uses feedback to multiplicatively decrease the rate of some process, in order to gradually find an acceptable rate. In a variety of computer networks, binary exponential backoff or truncated binary exponential backoff refers to an algorithm used to space out repeated retransmissions of the same block of data, often as part of network congestion avoidance. Examples are the retransmission of frames in carrier sense multiple access with collision avoidance (CSMA/CA) and carrier sense multiple access with collision detection (CSMA/CD) networks. For instance, in the CSMA/CD: (i) If a collision is detected during transmission of a packet, the node immediately ceases transmission and it transmits jamming signal for a brief duration to ensure that all stations know that collision has occurred. (ii) After transmitting the jamming signal, the node waits for a random amount of time and then transmission is resumed. The random delay ensures that the nodes, which were involved in the collision, are not likely to have a collision at the time of retransmissions. To achieve stability in the back off scheme, the BEB algorithm is used. A node will attempt to transmit repeatedly in the face of repeated collisions, but after each collision, the mean value of the random delay is doubled.

D. Binary Exponential Back off Algorithm

After a collision, time is divided into discrete slots with length equal to the worst-case delay (2τ). AFTER THE FIRST COLLISION, each station waits for 0 or 1 time slot before trying again. If two stations pick up the same random number, they collide again, P (collision) = 0.5. AFTER THE SECOND COLLISION, each station now picks up either 0, 1, 2 or 3 slot times, P(collision) = 0.25IF THE THIRD COLLISION OCCURS, each station picks the number of slots to wait at random, from ‘0’ to 23-1 „ In general, after ‘i ’ collisions, the random number between 0 to 2 i - 1 is chosen. However, after 10 collisions, the expansion process is halted at a maximum of 1023 slots. After 16 collisions, the NIC reports a failure to the computer. If the randomization interval for all collisions was 1023 max, the chances of collision would have been negligible „ But the average wait time be hundred of time slots, resulting into a significant delay „ On the contrary, if the stations delayed for either zero or one time slot, for say 100 stations, the only possibility of success would have been when 99 of the stations chose ‘1’ and one station chose ‘0’ or vice versa „ The randomization interval grows exponentially, offering pros of the two extremes and avoiding their bottlenecks

In distributed multiple access, a simple yet effective random backoff algorithm is widely used to avoid collisions. In particular, the binary exponential backoff algorithm [9] adjusts the contention window size dynamically in react to collision intensity. Such an algorithm is embedded in the IEEE 802.11 Distributed Coordination Function (DCF). DCF operates as follows before an attempt of data transmission is made; a station senses the channel to determine whether it is idle. If the medium is sensed idle throughout a specified time interval, called the distributed inter-frame space (DIFS), the station RTS CTS DATA ACK DIFS SIFS Backoff SIFS SIFS Slot time Deferred access.IEEE 802.11 DCF with RTS-CTS is allowed to transmit. If the medium is sensed busy, the transmission is deferred until the ongoing transmission terminates. A slotted binary exponential backoff procedure takes place at this point: a random backoff interval value is uniformly chosen in [0,CW − 1] and used to initialize the backoff timer, where CW is the current contention window size. The backoff timer keeps running as long as the channel is sensed idle, paused when data transmission (initiated by other stations) is in progress, and resumed when the channel is sensed idle again for more than DIFS. The time immediately following an idle DIFS is slotted, with each slot equal to the time needed for any station to detect the transmission of a frame (in the IEEE 802.11 term, MAC Service Data Unit (MSDU)) from any other station. When the backoff timer expires, the station attempts to transmit a data frame at the beginning of next slot. Finally, if the data frame is successfully received, the receiver transmits an acknowledgment frame after a specified interval, called the short inter-frame space (SIFS), which is less than DIFS. If an acknowledgment is not received, the data frame is presumed to be lost, and a retransmission is scheduled. The value of CW is set to CW min in the first transmission attempt, and is doubled at each retransmission up to a pre-determined value CW max. Retransmissions for the same data frame can be made up to a pre-determined retry limit, L, times. Beyond that, the pending frame will be dropped. In the case that the floor acquisition RTS-CTS mechanism is used, the same procedure is conducted except that an RTS-CTS handshake operation precedes the DATA-ACK exchange.

A uniform random distribution is used here, where CW is the current contention window size. The following equation is used to calculate the

Backoff time (BO): BO = (Rand () MOD CW)* aSlotTime (1).

The backoff procedure is performed then, by putting the node on a waiting period of length BO. Using carrier sense mechanism, the activity of the medium is sensed at every time slot. If the medium is found to be idle then the backoff period is decremented by one time slot.

Backoff time (BO) new = (BO) old - aSlotTime (2)

E.Bargaining Solution

In a transaction when the seller and the buyer value a product differently, a surplus is created. A bargaining solution is then a way in which buyers and sellers agree to divide the surplus.

The very common example for bargaining game is splitting a pie between two individuals. The sum of the shares of the pie claimed by both cannot exceed more than 1, otherwise each will get zero. If we denote these shares by θi and θj then θi+ θj >= 1 is required for a meaningful solution of the game where each get θi 0 and θj 0 payo§. When θi+ θj > 1 then and θi = 0 and θj = 0 . Standard technique to solve this problem is to use the concept of Nash Product.

A Bargaining Solution is defined as,

: (X,d) ® S,

where X Í R^2 and S,d Î R^2 . X represents the utilities of the players in the set of possible bargaining agreements. d represents the point of disagreement.

$$t_{Ab}(x) = Ax + b$$

In the above example, price Î [10,20], bargaining set is simply x + y £ 10, x ³ 0, y ³ 0. A point (x,y) in the bargaining set represents the case, when seller gets a surplus of x, and buyer gets a surplus of y, i.e. seller sells the house at 10 + x and the buyer pays20 - y.

Assumption Bargainging Set X is convex and bounded.

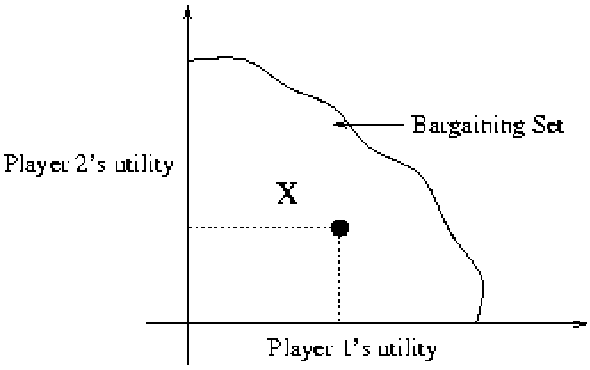

Fig 5: Bargaining Set

Properties of a Bargaining Solution

Nash gave four axioms that any bargaining solution should satisfy.

- Invariant to affine transformations.
- Pareto optimality.
- Independence from Irrelevant Alternatives.
- Symmetry

1. Invariant to affine transformations

An affine transformation t_{Ab} : R^2 ® R^2 is defined by a matrix A, and a vector b of the following form:

$$A = \begin{bmatrix} a_1 & 0 \\ 0 & a_2 \end{bmatrix}$$

$$b = \begin{bmatrix} b_1 \\ b_2 \end{bmatrix}$$

A bargaining solution is invariant to an affine transformation A,b,if F(X,d) = S

2. Pareto Optimality

A Pareto Optimal solution is one in which none of the players can increase their payoff without decreasing the payoff of at least one of the other players. A solution w is Pareto optimal if "w¢ Î W, $i , s.t. u_i(w¢) < u_i(w), or "i u_i(w¢) = u_i(w)where

$u_i(w)$ is the utility function for player i at outcome w. All points on the boundary of the Bargaining Set are Pareto Optimal solutions. In a bargaining situation, players would like to settle at a pareto optimal outcome, because if they settle at an outcome which is not pareto optimal, then there exists another outcome where atleast one player is better off without hurting the interest of the other players. Pareto optimal solutions are not unique in most cases.

In the earlier example, x + y = 10 is a pareto optimal frontier.

F(X,d) should be a Pareto optimal solution. Any bargaining solution should be better off than the disagreement point.

3. Independent from Irrelevant Alternatives

If S is the Nash bargaining solution for a bargaining set X then for any subset Y of X containing S, S continues to be the Nash Bargaining Solution. This axiom of Nash is slightly controversial unlike the previous two axioms, since more alternatives give you better bargaining power. However, this can be intuitively justified, by the folling argument: Let us say that the set Y has a NBS S' and S be another NBS of X (refer figure 2). Now S¢ Î Y, S Î Y and S¢ Î X, S Î X . In both the bargaining sets X and Y, both the options S, S' are available to the players. They should be expected to settle to the same outcomes. The presence of irrelevant alternatives in X should not influence the bargaining solution. Formally, if

F(X,d) = S

and
Y Ì X

S Î Y , d Î Y,

Þ F(Y,d) = S

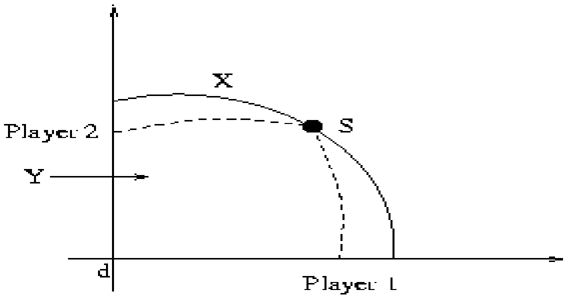

Fig 6: Independence from Irrelevant Alternatives

4.Symmetry

The principle of symmetry says that symmetric utility functions should ensure symmetric payoffs. Payoff should not discriminate between the identities of the players. It should only depend on their payoff functions. Put simply, symmetry implies the bargaining solution for region X = x + y £ 1, x ³ 0, y ³ 0, d = (0,0) , should be (1/2,1/2) as shown in figure 3. If both players have the same utility functions, then symmetry demands that both get equal payoffs.

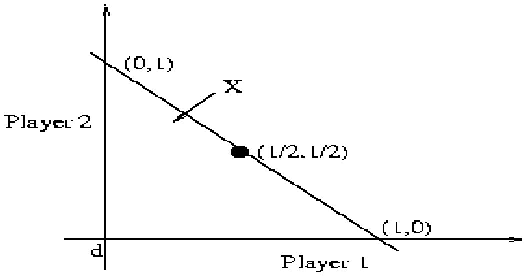

Fig 7: Symmetry

Nash characterized the NBS and proved that there is a unique solution satisfying the axioms given by Nash.

Theorem: If a tangent is drawn to the curve defining the boundary of the bargaining set at s - the Nash bargaining solution, it intersects the lines parallel to the axes and passing through the disagreement point (d) at points r and t. Then s = (r+t)/2 .

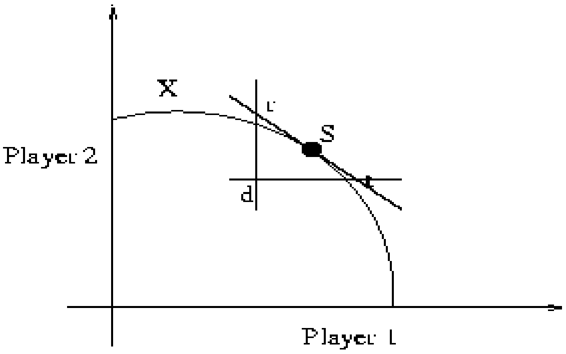

Fig8: The bargaining solution s = (r+t)/2

Proof: Let $d = (d_1,d_2)$ where d_1 and d_2 are the utilities of the two players in the event of disagreement. Let S be a pareto optimal point of X such that it is the midpoint of the line joining the points r and t. We will prove that S is a NBS of (X,d).

Lets define an Affine Function t_{Ab} where

$$A = \begin{bmatrix} [\,1/(t_1 - d_1)] & 0 \\ 0 & [\,1/(t_2 - d_2)] \end{bmatrix}$$

and

$$b = \begin{bmatrix} [\,(-d_1)/(t_1 - d_1)] \\ [\,(-d_2)/(r_2 - d_2)] \end{bmatrix}$$

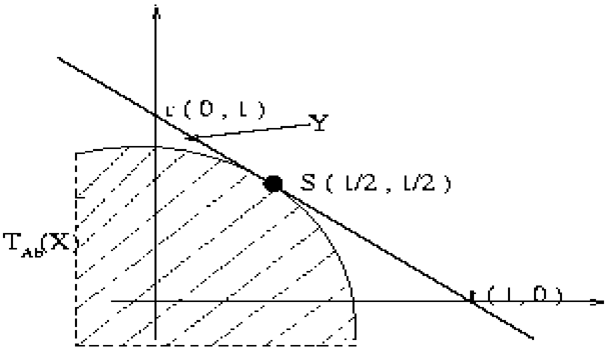

Fig 9:

$t_{Ab}(d)$ ® (0,0),

$t_{Ab}(r)$ ® (0,1),

$t_{Ab}(t)$ ® (1,0),

$$t_{Ab}(s) = \left(\frac{1}{2}, \frac{1}{2}\right).$$

Let $Y = \{(x_1,x_2):x_1 + x_2$ £ $1, x_1$ ³ $0, x_2$ ³ $0\}$. Note that $t_{Ab}(s)$ is a NBS for (Y,0). Also, $t_{Ab}(X)$ Ì Y (Since X is convex), (0,0) Î $t_{Ab}(X)$, $t_{Ab}(s)$ Î $t_{Ab}(X)$. By Independence from irrelevant alternatives, $t_{Ab}(s)$ is a NBS for $(t_{Ab}(X),t_{Ab}(d))$ Therefore, s is a NBS for (X,d) , and

$$s = \frac{r+t}{2}.$$

Generalised Nash Bargaining Solution

If the players were asymetric in their bargaining strengths, then NBS can be generalized by dropping the symmetry axiom. In this case the NBS satisfies s=ar+bt where a and b are bargaining powers of the two players, and a+ b = 1

NBS as a Solution to the Alternating Offers Game

Define the alternating offers game as an extensive form game (as done in last lecture). In this game, two players bargain to settle on a price. First of all player 1 makes an offer to player 2 . Player 2 can either accept or reject. If player 2 accepts the deal takes place, otherwise he incurs a discount on his utility and makes an offer to the player 1. The game continues like this until someone accepts the offer. Let $u_1(x)$ and $u_2(x)$, x Î (0,1) be the utility functions of the two players. If agreement settles in time t at x^*, their payoff will be $((d_1)^t u_1(x^*), (d_2)^t u_2(x^*)$. The Subgame Perfect Equilibrium for this game is defined by x^* , y^* s.t.

$$d_1u_1(x^*)=u_1(y^*)$$
$$d_2u_2(y^*) = u_2(x^*)$$

Player 1 offers x^* and accepts any offer that is atleast y^*. Similarly player 2 offers y^* and accepts anything that is atleast x^*. If $d_1 = d_2 =d$, then this is symmetry.

Theorem: Nash Bargaining Solution is same as the solution to the symmetric alternating offers game in thelimit d® 1

Nash product as

$$g(x) = (x_1 - d_1)(x_2 - d_2)$$

To prove the theorem to use the following lemma.

Lemma:

NBS S of (X,d) is the unique solution S Î X that maximizes the Nash product g(x).

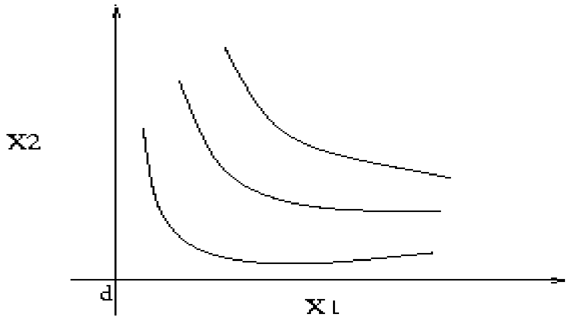

Fig 10: NBS
Maximizes g(x) = $(x_1-d_1)*(x_2-d_2)$

Let x^*,y^* correspond to the solutions of the alternating offers game. Now,

$$du_1(x^*) = u_1(y^*),$$

$$du_2(y^*) = u_2(x^*).$$

Now,

$$\begin{aligned} g(x^*) &= u_1(x^*)u_2(x^*), \\ &= u_1(x^*).\ du_2(y^*), \\ &= u_1(y^*)u_2(y^*), \\ &= g(y^*). \end{aligned}$$

In the figure, the curve facing outward is the curve for g(x) = k, where k is a constant. The farther we shift the curve from the origin, more value i attain. Hence in the limiting case, the value of g(x) is maximum when it barely touches the convex curve, i.e. $x^* = y^*$. In the limiting case, when d is close to 1, $x^* = y^*$. Therefore x^* maximizes g(x) and x^* Î X . Hence,
Þ x^* is Nash Bargaining Solution for (X,d).

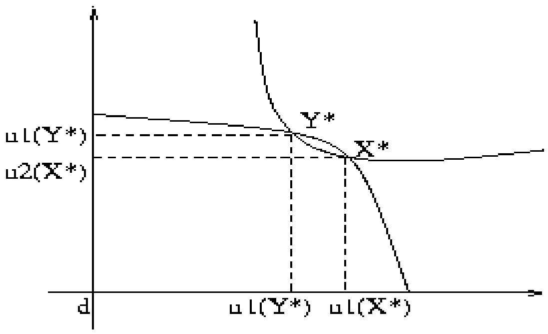

Fig11: Correspondence with Repeated Game Bargain

Application of Bargaining

Money to be divided between two players M = u1 + u2 (7) Nash product N = u1u2 (8) The origin of this bargaining game is the disagreement point d(0, 0), the threat point. Here the utility of player one (u1) is plotted against the utility of player two u2 and the line u1u2 is the utility possibility frontier (UPF). Starting of bargaining can be (0, M) or (M, 0) where one player claims all but other nothing. But this is not stable. users and counter users will be made until the game is settled at u = 1 2M, 1 2M where each player gets equal share.

Numerical Method of Bargaining

The Nash bargaining solution is the values of u1 and u2 that maximise the value of the Nash product u1u2 subject to the resource allocation constraint,u1 + u2 = 1000. This bargaining solution fulfils four different properties: 1) symmetry 2) efficiency 3) linear invariance 4) independence of irrelevant alternatives (IIA).

1. Symmetry implies that equal division between two players

2 Efficiency implies no wastage of resources u1 + u2 = M or maximisation of the Nash product, u1u2.

3 Linear invariance refers to the location of threat point as (200, 200). If u is a solution to the bargaining game then u + d is a solution to the bargaining problem with disagreement point d.

4. IIA implies irrelevant alternatives are not discussed in the game.

IV Conclusion

In cooperative communication a user can share the resources of other users to convey their message to the destination. Two or more active user in network can share the information and jointly share the information .this results in greater reliability and reduction of cost. Identified the similarities between CRN networks apps and how CRN can be used by sensor for reliable communication.

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