Handling competitiveness in Next Generation Networks using Game theory

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ABSTRACT
From the last two decades the communication networks were undergoing many changes, whereas few years ago the network was exclusively used to connect IT users. Ubiquitous and personal computing is an emerging technology in the networking field. Every modern business is completely dependent on enterprise network; it has become the most demanding areas of business communication and decision making. The idea of the network as a service is admired because of low cost network implementation and multivendor network. IT organizations are starting to witness a massive increase in video traffic. Consider by 2020 the Internet video alone will account for 60% of all consumer traffic. By 2020, there will be nearly everyone will be connected to the Earth. The huge network of mobile devices needs to be handled not just as demands of employees but as a business necessity.

The paper presents an overview of Next Generation Networks (NGN). In Cognitive Radio (CR) various spectrum sensing techniques are used. The radio spectrum scarcity issue can be efficiently handled by cooperative game theory approach.

General Terms
Next Generation Networks, Cognitive Radio, Game theory

Keywords
Radio spectrum, Resource allocation, Dynamic spectrum access, Cooperative game theory.

1. INTRODUCTION
NGN provides an outlook of future services to the end users and opportunities for traditional network operators and new players. Internet Service Providers (ISP) providing communication services based on Internet Protocol (IP) is not only a lower cost solution but also with enhanced features over traditional telecom services. The vast development of technology not only hail many players in telecom sector, but also complicates the infrastructure development decisions. In short the telecom operators should become more than an ISP and telecom operator should apply a model of operation driven by the needs of customers [1]. The objective of NGN is to connect devices, persons and resources irrespective of location, distance and time. Today's wireless networks are regulated by governmental agencies and are assigned to license holders or services on a long term basis for large geographical regions.

The fixed spectrum assignment policy generally served well in the past, but there is a remarkable increase in the access to the limited spectrum for mobile services in the recent years. This increase is damaging the effectiveness of the traditional spectrum policies. The limited available spectrum and the inefficiency in the spectrum usage demand a new communication paradigm to exploit the existing wireless spectrum opportunistically [2, 3]. To solve the inefficiency problem Dynamic Spectrum Access was proposed. DARPAs approach on Dynamic Spectrum Access network aims to implement the policy based intelligent radios known as cognitive radios [4, 5]. Usage of existing spectrum can be improved through opportunistic access to the licensed bands without interfering with the existing users. Cognitive radio (CR) is treated as key enabling technology in NGN. Cognitive radio techniques provide the capability to use or share the spectrum in an opportunistic manner. The main challenges for CR are selection of best available channel and to have adaptive network protocol available to spectrum. The main functions of CR in NGN can be identified as follows:

1) Spectrum sensing: Detecting the presence of licensed users when a user operates a licensed band. It also detects unused spectrum and sharing the spectrum without harmful interference with other users.

2) Spectrum management: Capturing the best available spectrum to meet user communication requirements.

3) Spectrum mobility: Maintaining seamless communication requirements during the transition to better spectrum.

4) Spectrum sharing: Providing the fair spectrum scheduling method among coexisting NGN users. i.e. vacating the channel when a licensed user is detected in the spectrum.

These functionalities of NGN facilitate spectrum aware communication protocols.

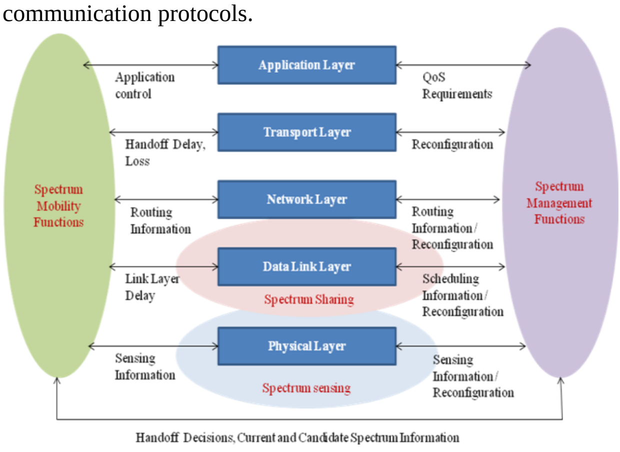

Fig. 1: NGN communication functionalities [3].

The NGN communication components and their interactions are illustrated in Fig. 1. The number of interactions signifies that NGN network functionalities demand a cross-layer design approach. i.e. spectrum sensing and spectrum sharing cooperate with each other to enhance spectrum efficiency. In spectrum management and spectrum mobility functions, application, transport, routing, medium access and physical layer functionalities are carried out in a cooperative way, considering the dynamic nature of the underlying spectrum

2. NGN ARCHITECTURE

NGN functional architecture has been agrees among different standardization bodies. Based on ITU-T NGN functional architecture is abstracted in Fig.2

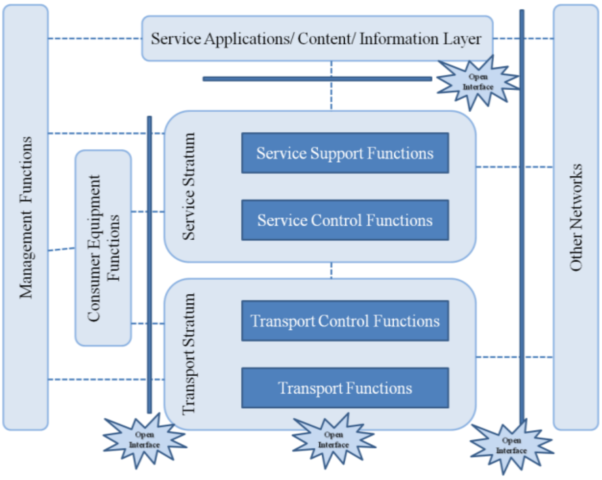

Fig. 2: ITU NGN Functional architecture [1].

The NGN is composed of domain of service stratum, transport stratum, services/ applications/contents/information layer, management functions, consumer equipment functions and other networks. The open interface between the service stratum and service/ application/ content/ information layer, which enables a standardized application creation/execution environment; easy service creation using application programming interfaces, which is called with high level programming languages.

The service stratum and transport stratum separation enables the flexibility to add/maintain/remove service/application/content/information without any impact on transport layer; optimized usage of multiple access and core transport technologies to form end to end connectivity across multiple terminals, different access technologies and different core transport technologies.

3. NETWORK AND SERVICE EVOLUTION TOWARDS NGN

Now a day's several types of physical communication network are running simultaneously. Each type of network provides some specific services like the fixed telecommunication network was mainly designed for voice communication, whereas mobile communication network was designed for voice and text communication with the mobility features. The cable network was designed for TV and radio broadcasting services using coaxial cables. In spite of changes in networks to network and service provisioning, every legacy network is contributing its best to provide Internet services on it. Services like email, chat, web browsing, VoIP etc. Each type of network is trying to enhance its capabilities and trying to provide services to others like telecom network is providing broadcasting services, internet service providers are providing telephony services and cable network is providing Internet access [1].

Major steps of evolution in network and services are; service convergence and access network development, IP-based service conversion and IP network development, network integration and service expansions.

Service convergence means the same service is provided to customers from different network. E.g. customer can watch TV programs on the computer using Public Switched Telephone Network (PSTN), on a television set via the cable network, on mobile phone via mobile network. Technology used in each network is different, so the delivered quality of service (QoS) could also be different. Every service has QoS requirement and for that parameters like bandwidth, delay, jitter, data error rate etc. plays an important role.

Access development means increased access bandwidth, reduced delay and support for the portability and mobility.

IP based service conversion means the native services associated with legacy network are converted to IP based. E.g. traditional telecom voice service is converted to VoIP. This conversion decouples the services from the underlying transport network i.e. without touching the underlying network services can be added or removed. e.g. A laptop can access the same television program via fixed, mobile and cable network using an appropriate adapter. The changes in the underlying network have no impact on services as the decoupling of services is done.

The IP network development transforms the best effort IP network of today with legacy networks into a manageable IP network for delivering IP-based services with required quality and security.

Network integration adds a common transport control above all the access and core transport networks. The transport control layer is responsible for setting up and maintaining end to end connectivity with the core transport network as per the service requirement.

The service extension is to place service stratum and the open interfaces to enable the creation and delivery of prosperous services for end users. Different networks such as fixed, mobile and cable provide similar functions which are unified in service stratum. The service support functions include call setup and location information to enable creation of advanced services, applications, content and information. A Service control function includes the streaming to guarantee service delivery to end users with sufficient quality and security. The open interface is defined by group of APIs and used to call the network services in high level languages. E.g. the OSA/Parlay API include call control, user interaction for exchanging data between an application and end users, mobility for obtaining the location and status of an end-user or multiple end-users, mobility for obtaining location and status of end user, terminal capabilities for obtaining end user terminal capability, data session control to setup and maintain data session, account management for accessing accounts of end user, content based charging for charging usage of services or data, generic messaging for accessing messaging box of SMS , multimedia messaging etc., connectivity management for providing QoS, policy management, presence and availability management.

4. COGNITIVE RADIO

Resource provisioning is one of the most demanding and important aspect in communication networks. Radio resources are limited. A recent study concludes that most of them have been already licensed to existing operators. The radio spectrum studies showed that, licensed spectrum remains unoccupied for large amount of time [7, 8]. Spectrum access means, to enhance the efficiency in the usage of spectrum in a specific geographic region, CRs access spectrum holes left by the licensed user's system (primary users) as secondary users. i.e. Spectrum access happens in time, frequency and space.

Dynamic spectrum access is a promising approach to alleviate the spectrum scarcity that wireless communications face today. In short, it aims at reusing sparsely occupied frequency bands while causing no (or insignificant) interference to the actual licensees. The bandwidth requirements of emerging technologies can be fulfilled up to a certain extent by such allocation. The following figure shows dynamic spectrum

access (DSA).

Cognitive radio system requires four major functions that enable it to opportunistically use the spectrum [10]. Spectrum management consists of spectrum sensing, spectrum decision, spectrum sharing, and spectrum mobility [11].

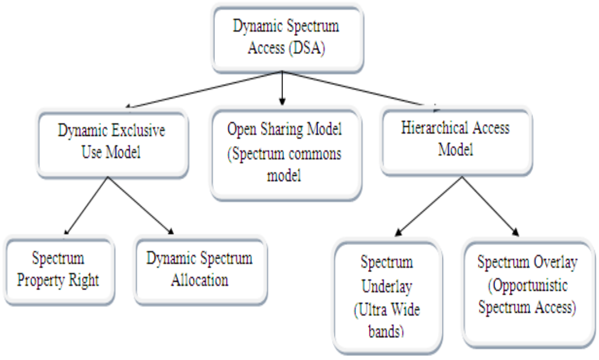

Fig. 3: Dynamic Spectrum Access (DSA) [9]

5. GAME THEORTIC APPROACH

Considering application scenarios in which users are "selfish" and act non-cooperatively to maximize their own interests, the performance of such networks will deteriorate dramatically because of the inefficient competition for the wireless resources among selfish users [6]. Game theory is a successful economical tool to study the behavior of selfish users and to ensure the cooperation between users.

Different game models used to achieve goals with following aspects

1) Non cooperative static games:

Traditionally pricing chaos is investigated in this approach. To control the radio resource usage, price approach is used. It can be treated as a tax paid against the resource utilization. The non-cooperative power control game can be used for distributed resource allocation in nonlinear way. The game model can be converted to linear by using multiple related games and multiple utility functions for power-control. Another approach used is referee based approach in which referee monitors the performance of game. If the performance is good it does nothing otherwise the referee will reconcile the game rules for performance enhancement. The non-cooperative game schemes are used to conduct channel assignment, adaptive modulation and power control for multicell OFDM network [6].

2) Non cooperative repeated game

The goal for the non cooperative repeated game is to punish any deviating greedy users that do not cooperate. Selfish users would transmit non-cooperatively with high rate, which causes high collision probability in the multiple-access protocols and results in low system performance. A repeated game framework is proposed to enforce cooperation among selfish users.

3) Game with cooperation

Wireless network performance can be improved by cooperative transmission. Two level games are proposed for sources and relays to achieve optimal resource allocation in a distributed way. The goal, cooperative game design is to provide benefits of cooperation to autonomous users. Incentives and mutual benefits can be obtained by bargaining process. This approach can be used to allocate channel, rate and power to multiple users within a cluster of wireless networks. The new fairness criterion is a generalized proportional fairness based on the coalition.

Cooperative game theory:

A cooperative game doesn't mean the game where actual players do cooperate, but as games in which any cooperation is enforceable by an outside party. The outside party can be e.g. judge, monitor, or police. There are two major components of cooperative game theory. They are (1) the bargaining solution (2) coalition concepts.

1) The bargaining problem:

The bargaining problem of cooperative game theory is, Let K = {1, 2, 3, 4…K} be a set of players and S is a closed and convex subset of U^k to represent the set of feasible payoff allocations that the players can get if they all work together. Let u^i_{min} is the minimum payoff which i^{th} payer will expect otherwise the player will not cooperate. Suppose $\{u_i \in S \mid u_i \geq u^i_{min}, \forall i \in K\}$ is a nonempty bounded set. Define $u_{min} = (u^1_{min}, u^2_{min}, \ldots, u^K_{min})$ then the pair (S, u_{min}) is called a K-person bargaining problem.

2) Coalition concept:

Coalition S is defined to be a subset of the total set of player N, S ∈ N. The user in a coalition tries to cooperate with each other. The coalition form of the game is given by the pair (N, v) where v is a real value function, called the characteristic function. v(S) is the value of the cooperation for the coalition S with the following properties:

i. $v(\phi)=0$

ii. And if S and T are disjoint coalitions ($S \cap T = \phi$) then $v(S) + v(T) \leq v(S \cup T)$

A Shapley function ϕ is a function that assigns to each possible characteristic function v a real number, i.e. $\phi(v) = [\phi_1(v), \phi_2(v), \phi_3(v), \ldots \phi_N(v)]$, where $\phi_i(v)$ represent the worth or value of player i in the game.

The Shapley value is just the average payoff to the players if the players are entered in completely random order i.e.

$$\phi_i(v)=\sum_{S\subset N, i\in S}\frac{(|S|-1)!(N-|S|)!}{N!}[v(S)-v(S-\{i\})] \quad (1)$$

Coalitional games are defined into three distinct classes

i. Class I : Canonical (coalitional) games

ii. Class II : Coalition formation games

iii. Class III: Coalitional graph games

In canonical (coalition) games, the utility or value of a coalition does not depend on how the players are interconnected within the coalition. However, the underlying communication structure between the players in a coalitional game can have a major impact on the utility and other characteristics of the game, in certain scenarios [12, 13, 14].

To demonstrate the difference between characteristic and partition forms, let us consider a 5-players game with N ={Ojasvi, Tara, Tina, Farah, Fatima} and let S1 = {Ojasvi, Tara, Tina}, S2 = {Farah}, S3 = {Fatima}, and S4 = {Farah, Fatima}. Given two partitions P1 = {S1, S2, S3} and P2 = {S1, S4} of N, evaluating the value of coalition S1 depends on the form of the game. If the game is in characteristic form, then $v(S1,P1) = v(S1,P2) = v(S1)$ while in partition form $v(S1,P1) \neq v(S1,P2)$

The players are interconnected and communicate through pair wise links in a graph in many coalition games. In such cases the characteristic form and the partition form may be unsuitable since, in both forms, the value of a coalition S is independent of how the members of S are connected.

6. CONCLUSION

In this paper, the architecture of Next Generation Networks (NGN) and spectrum sensing in cognitive radio technique is elaborated. One of the techniques of dynamic spectrum access in cognitive radio networks is game theory which is widely used in this area because it can achieve equilibrium between users that provides efficient spectrum management. This paper explains in detail cognitive radio and its main functions spectrum sensing, spectrum decision, spectrum sharing and spectrum mobility. Different methods for designing dynamic spectrum access are also briefly discussed. This survey can be an ideal introduction for wireless and cognitive radio domain naive research students.

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