Practically Pioneering - Dynamic Spectrum Sharing (and Dynamic Time Limited Trade)

(Road Ahead for Indian Telcos)

Genre: Semi Technical and Commercial

Currently, Spectrum allocation is static in nature, where a bandwidth is licensed for a fixed period for exclusive usage. Spectrum sharing through dynamic allocation of time slots or actual resource units for an agreed time interval is carried out using a cognitive network, which actively monitors several factors in the external and internal radio environment, such as radio frequency spectrum, user behavior and network state, peer network behavior etc. This assists in matching the demand and supply closely, thereby increasing the spectrum usage in a more efficient manner. As of now, this concept is presented in context of GSM spectrum sharing only; however, with new Radio Access technologies (RAT) like OFDMA, WCDMA etc. the concept can be easily scaled further to meet challenges of spectrum scarcity in the bands for these technologies too (e.g. read Reliance's Jio 4G network and Airtel's 4G network) . In future, the nodes will be multi standards, championing the cause of Spectrum Sharing through Dynamic Resource Allocation for different RATs.

Dynamic Spectrum Sharing is the need of the hour for efficient usage of scare spectrum by allowing an equal opportunity to all the operators. The Sharing of Spectrum amongst operators (users) can easily be scaled down to the micro level i.e. Circle wise/ region wise as far as Geography is concerned while in order of seconds/minutes/days as far as time is concerned, thereby relieving the Regulator of getting involved in constant tussle amongst the operators by designing a sound set of protocols for sharing of spectrum.

India could be the first country implementing the sharing on a massive scale as far as GSM is concerned; the works related to it has been in contemplation in many countries, with research work already done to support the Proof of Concept in Countries like Finland, Germany, USA and Japan. These works have been explored by US Defence Research Department DARPA on wide radio bands 0-3 GHz. In USA, FCC has considered allowing sharing of unused portions of TV band, Europe has done a comprehensive study for the European Commission on conditions and options in Secondary spectrum trading is done, and Japan has implemented a frequency band on registration basis (4.9 GHz – 5.o GHz) to promote shared use of spectrum. [2]

Dynamic Sharing is the only path forward to resolve the spectrum management issues in Indian context.

In this paper, concept of dynamic sharing is deliberated assuming ONE channel sharing only. But with a pool of more channels available, it will offer ample opportunity for operators to have access to larger pool, thereby enhancing their capacity and QoS and decreasing the complexity of the process. Some key terms critical to understand and make sharing successful are mentioned below:

- **Cognitive Radio Terminal (CR)**: The terminals that can sense the behavior of a user at a particular channel adapt its own transmission and dynamically accesses that channel as per spatial and temporal requirements. Cognitive Radio is based on Software Defined Radio technology (SDR) according to which the transmission parameters of a terminal can be changed using the software , like modulation, output power etc**. Each Operator has its own CR.**
- **Spectrum Broker (SB) i.e. COORDINATING AGENCY:** An Independent company having permanent right over the spectrum, only granting time bounded lease to the requesters (user/operators) for a particular region/circle-area .This centralized body will work to achieve coordination amongst all the stake holders (operators). The leasing conditions will specify the time, extent of spatial region, maximum power etc for operators/ CRs to use.
- **Charging Basis:** Bandwidth will not be traded as a resource; instead the users (operators) will be charged either for the received Signal to Interference ratio (SINR) or for the allowed transmits power in the particular channel in use.
- **Spectrum Mediator (SM)**: Spectrum users are part of operators responsible to manage spectrum allocated (through sharing) to that operator and also coordinate on behalf of the Operator with the SB/COORDINATING AGENCY. Each Operator maintains its own spectrum mediator (SM).
- **Spectrum Server (SP):** SP is a database serving the Operators or CRs for learned action for respective frequencies/channels in terms of modulation, coding, frames and power.
- **Dynamic Frequency Broker (DFB):** It is a local computerized frequency coordination authority keeping complete list of frequency assignments within an area and keeps an updated terrain propagation path loss model of its area. It has all the information about active CRs (transmitting).

Cognitive Radio (CR) that requires transmitting on a given channel as per its requirement should seek permission from Spectrum Broker. Any vague transmission on a particular channel without authority shall amount to penalty as decided by Spectrum Broker. Regarding this, one can take cue from Collision Sense Multiple Access, Collision Detection Networks (CSMA/CA), the standards which have been incorporated in Ethernet, WI-Fi 802.11 standards too.

There are two **type of users** viz. **Primary (PR or CR1)** and **Secondary User (CR2).** Primary User has the first right while the rest are all secondary rights transmitting only when the channel is idle. CR2, CR3, CR4 etc are secondary while CR1 is a primary user.

SB (i.e. COORDINATING AGENCY) can classify itself as PR/CR1 (primary user) while others CR2, CR3 etc, as secondary users **OR** all operators can be classified as secondary users with no primary user (PR/CR1 can be COORDINATING AGENCY only in emergency cases or be taken as a reference thereby making the competition or access to channels to operators on equal opportunity basis.

However, we are considering CR1 as primary user with priority, for the sake of making it inclusive in nature i.e. primary user may use its right for first use of spectrum anytime, (say) for emergency issues or as defined in the protocol.

There are 3 architectures (that will assist in protocol designing) of sharing in brief:

1. **Coordinated Spectrum Sharing:** All primary and secondary users i.e. operators are connected to SB. A request of accessing a particular channel is sent by a CR (operator) via the SM (spectrum Mediator) to the SB. The SB will then tackle multi-users that apply to participate in i-channel (i.e. particular ONE channel in demand). SB accordingly generates the IT-backhaul link (Information Technology systems) necessary for intermediate sharing of the transmission time fairly among secondary users. Each of CR1 and CR2 will share information using on-line XML communications (IT systems) with the SB to avoid interfere each other and/or the primary user. Earlier than starting transmission, CR can download the PR (reference) parameters (modulation, coding, transmission power, routes, and broadcasting area) from the SB.

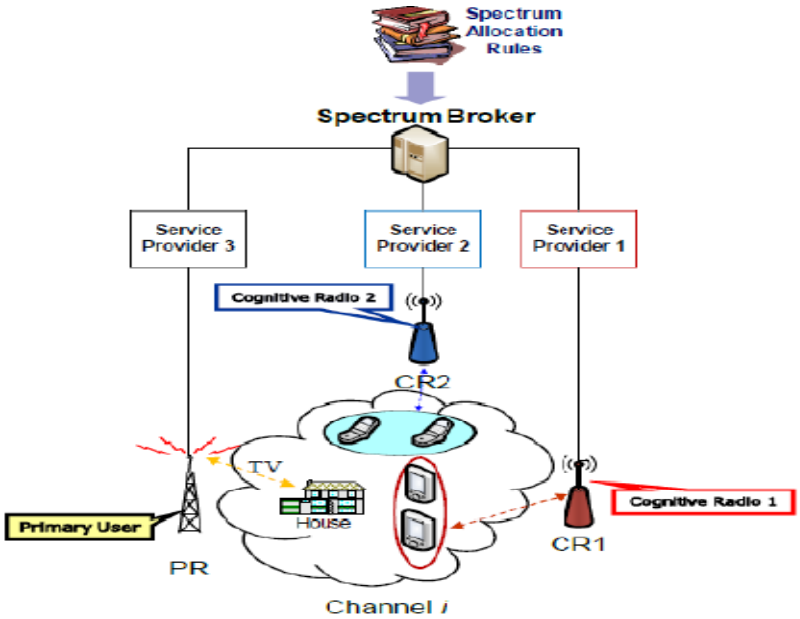

Fig.1. Coordinated Spectrum Management Solution

Advantages: A Less complex system, allowing each user demanding particular channel having access in a time coordinated manner.

Disadvantages: Centralized system and implementation at a macro level implies only rough estimation of the actual demand at the micro (district level)

2. **Distributed Spectrum Management:** In this case, all the Operators (PR/CR1, CR2, CR3 etc) share information about the channel amongst each other and use their own Spectrum Database to determine the channel information and other technical parameters. For two operators, (say) CR1 and CR2 wanting the channel at the same time, they play a game (based on game-theory algorithm) to win the access for that channel for a particular interval of time.

   But since, in the event of idle time for i-channel, CR2 or the channel in possession will be selfish and try to prolong the usage. To circumvent this, CR2 in need of channel for a limited time applies for Urgent Secondary User Coexistence (USUC) using Common Spectrum Control Channel (CSCC) protocol. In this case, CR1 (Primary User already with priority right) is responsible for generating the backhaul (IT systems) portions for CR2 while giving itself the first opportunity to start transmission at any time. Any secondary user (operator) decides to leave the channel, should inform all the CRs (operators) with such a decision.

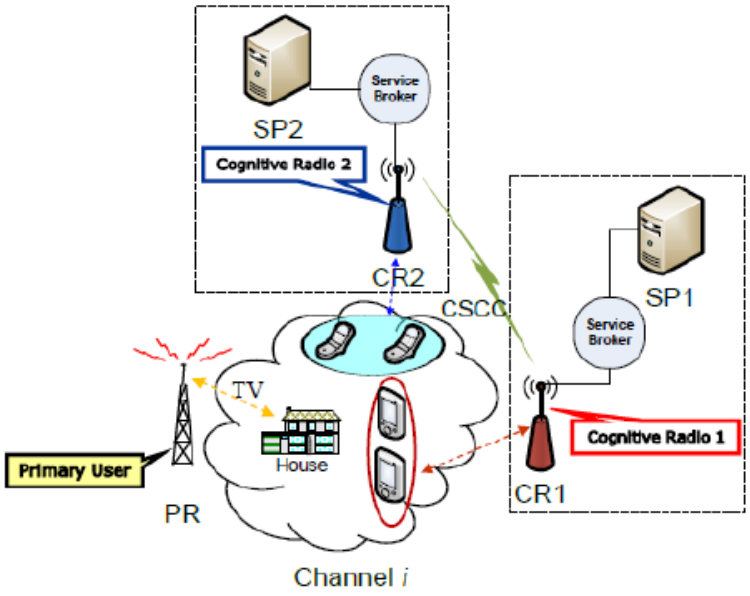

Fig.2. Distributed Spectrum Management Solution

Advantages: More accurate estimation of the demand resulting in more efficient usage of the spectrum, more throughputs per channel, lesser chances of outage when compared to static and centralized/coordinated system

Disadvantages: Complex than the Centralized cooperative system

3. Hybrid Spectrum Management (Coordinate at Centre, while Distributed at Micro Level):

Both above scenarios coordinated and distributed are bridged to create a new hybrid spectrum sharing management. When CR2 intends to transmit on channel i it sends a request to the spectrum broker. The SB, as shown in fig (3), assesses i-time ease of use. Keeping in hand the general rules for transmission and coexistence etiquettes, the SB determines the order of 'n' of CR's that can co-exist on a channel. Once decided and communicated, then Mutually CR1 and CR2 start to play the game of coexistence with each other.

Hence, they can share the channel not just on time division basis, but on- end users demands also. Both CR's can talk to each other using CSCC and exchange other arrangements. One of those CR's will be the master and the other the slave. The senior i-user is to head all other n-secondary radios for its long experience on the channel situations. CR1 will be in charge in this group and any other arrangements will be issued according to negotiations between all CR's. All updates should be passed to the SB by the master.

This will allow the SB to deal with other operators requirements and to vacate the information's channels for other users. When any of the CR's using channel-i decides to move away it informs the spectrum broker for agreement and at the same time the other group members through CSCC.

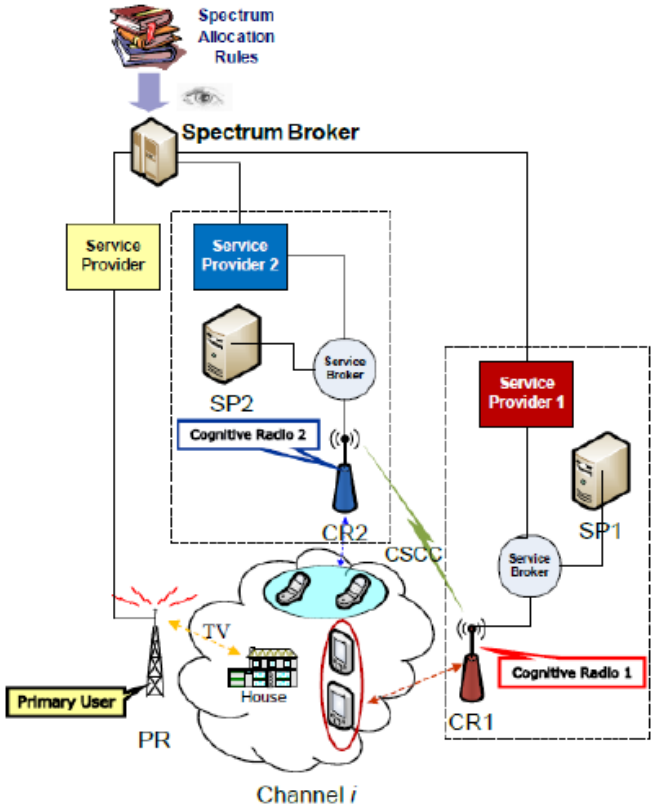

Fig.3. Hybrid Spectrum Management Solution

Advantages: Best of both i.e. centralized and distributed approach. In Hybrid management approach, more closely the coordinated (/centralized) system follows the Distributed system with short time adaptations, the better will be the resultant throughput.

Takefumi Yakada et al. [2] conducted computer simulations with 8 operators (users) competing for the transmission resources, depicting the advantage of these approaches over the current (static) approach:

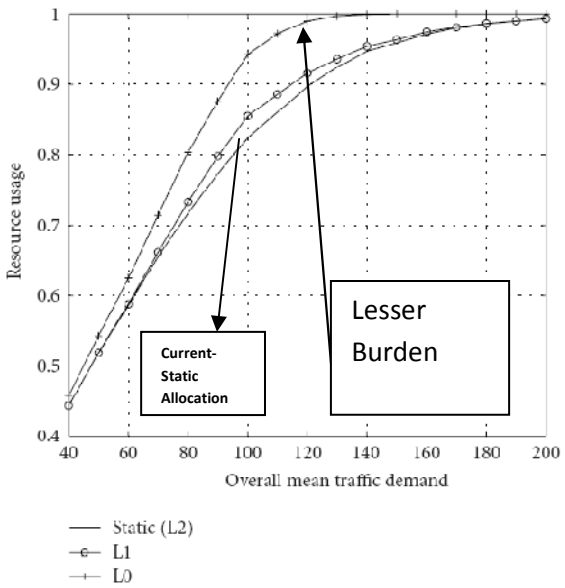

Figure 4: Overall resource usage at different market levels of the centralized spectrum trading approach.

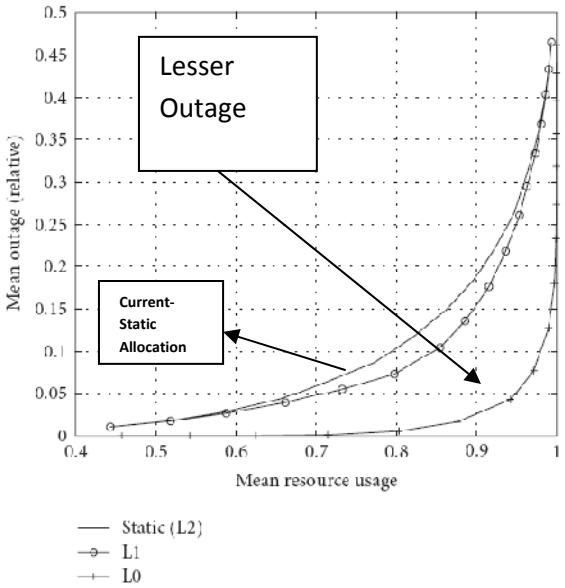

Figure 5: Operator-centric outage measure plotted against the mean resource usage found in Figure 4.

where L1 is a centralized/coordinated approach while L0 is the distributed approach.

Conclusion: This is an implementable project, quiet similar to the lines of network of Mobile Network Portability as IT back haul network is to be developed with an Independent Spectrum Broker (i.e. COORDINATING AGENCY) sharing information about channels to use. What channel is to be given to what user/operator at what time will depend upon the protocol designing, whether based on Game theory, dynamic bidding process (micro trading), Queuing Theory etc. Once, the decision to implement this, it shall be followed by protocol designing taking views of all the stakeholders so that fairness in the system can be maintained. Such novel implementation would not only mean solving the current issues but also making our Spectrum Management system future proof with new Radio technologies in both Licensed and Un-Licensed bands.

Reference:

Along with **PROJETO CONSULTING** *Inputs and Analysis, the paper has taken research references from following:*

1. *"Multi- Operator Cognitive Radios Sharing One Channel" from Brunel University- UK.*
2. *"Resource Distribution Approaches in Spectrum Sharing Systems" from NTT DoCoMo. Inc- Japan, Kalrushe University- Germany and DoCoMo Communications Laboratories-Munich, Germany*

The Road Ahead for the Telcos – Spectrum sharing and subsequent Dynamic Trading

It is well known that the performance of some of the operators (also depicted by TRAI's per MHz subscriber efficiency data) is not picking up, rather their growth has continuously dwindled or remained stagnant while there are some operators who are reeling under pressure having per Mhz subs density as high as close to 1 million per Mhz in cities like Delhi.

It is then imperative that new avenues for PSU's (and such Telcos) revenue regeneration methods are found such that the scarce resources are put to use more efficiently.

As a matter of fact, if sharing and further dynamic trading is allowed, PSU operators may also even stop contemplating giving back their respective 4G spectrum that was awarded to them by default at bid price.

Hence it is recommended that Telcos having underutilized chunk of spectrum based on per Mhz mm subscriber efficiency be put to a common pool where in dynamic trading can happen for sharing purposes.

Some more nuts and bolts of this Sharing Cum Trading Scheme:

1. The underutilized excess spectrum should be brought into the common sharing and trading pool
2. This excess sharable spectrum can be used by interested operators on need basis *(e.g. Operator A as a Lead sponsor of a Sports event expects/anticipates a heavy traffic data during National Games or a Cricket Tournament may in advance do Trading for excess spectrum for a particular tournament period)*
3. The private operators based on a platform, offered and managed by PSU, bid for the required spectrum for their use (*based on protocols so developed*)
4. This excess spectrum can be allocated in a dynamic mode so that those who require it most at any given point of time are able to access and as soon as the requirement recedes/lessens, the spectrum gets back to the Coordinating Agency managing Sharing and Trading
5. No more than 1 MHz (suggestive limit) should be dedicatedly given to any operator at any given time so that maximum number of operators can be adjusted in shared spectrum, however if the system feels that the requirement for one of the operator is higher than any other and other operator(s) may not require additional spectrum at that given point of time, it can allocate further 1 MHz to this needy operator.
6. Since spectrum is dynamically allocated, there is no requirement of operator specific sharing agreements as well, as long as pre-sharing and trading agreements are signed on a yearly basis.
7. In order to ensure that operators do not resort to spectrum hoarding, various algorithm, protocols and checks can be developed within the system *(as mentioned in the technical note-* ***Practically Pioneering - Dynamic Spectrum Sharing (and Dynamic Time Limited Trade)*** *)*
8. The contagious spectrum concern of some operators will also be dealt as part of future detailed protocols that will talk about priority and probability issues.

A lot of academic and technical research and work has been done over the years for successful spectrum sharing, and many countries now have spectrum sharing platform available. However what is being

proposed could be first of its kind in the world Implementation. In long term this can be a solution to spectrum scarcity once available spectrum starts exhausting upon complete allocation.

(*Please refer– 'Technical Note' discussing the concept in detail-* ***Practically Pioneering - Dynamic Spectrum Sharing (and Dynamic Time Limited Trade***)

The benefits of this approach are many and far-reaching:

1. Opens up an additional revenue stream for PSUs and others
2. Government gets incremental spectrum usage charges and license fee generated by users of this shared pool of spectrum i.e. brokerage tax charges for each commercial transaction that follows sharing
3. Many other spectrum bands can also be brought under its purview. (3G, WiMAX...etc.) leading to technology band agnostic regime as market forces will appropriately determine the right price
4. Technically the scarce resource is being utilized efficiently
5. Improvement in QoS (and less outages) for operators by addressing spectrum fragmentation issues
6. Gives access to a larger pool of spectrum to the *sharers* thereby enhancing their network capacity to optimum levels as operators.
7. Greater welfare gain and a right step towards sustainable development of the industry (e.g. lesser towers, lesser power consumption thereby moving towards more eco-friendly and sustainable approach)
8. Improved focus on R&D for better frequency management that can help developing visionary policy frameworks
9. Helps in reducing the menace of unplanned/improper designed base Stations that violates ICNIRP guidelines – thereby keeping our society and neighborhoods safe
10. Like MNPO Database, this will lead to greater information integration as far security , Location Based tracking and IMEI issues are concerned

How this should be achieved:

Once Coordinating Agency successfully demonstrates that it can effectively manage the pool of its spectrum with multiple operators through sharing wherein the proof of this concept is established, then the Coordinating Agency **could** be allowed to form a majority owned subsidiary.

This subsidiary that will manage spectrum sharing and Trading process, may (only suggestive/indicative example) have the following shareholding:

1. Government of India through Coordinating Agency 51%
2. In hands of general public– 20% with no individual holding >0.5%
3. Balance 29% equally held by each of the licensed UASL operator with wireless services (including PSU as operator)
4. If at any point of time in future any new wireless entrant is allowed the 29% should automatically be divided again with this new entrant inclusive i.e. at any given point of time all UASL wireless operators will hold equal share of this subsidiary

Important Considerations:

The Coordinating Agency does not become spectrum allocation body, rather that role remains with the DoT. Coordinating Agency only becomes a manager of spectrum sharing and administers trading thereby ensuring the effective and efficient spectrum utilization for stakeholders' benefit. In the process, it also gets revenue out of it which can be put to better social obligatory roles performed.

It is important to note that trading could not be just one time event if the primary intention is to increase efficiency and bring level playing field. TRAI and many other operators may see dynamic trading as purely a concept note as of now, but it is imperative to look from this perspective.

The paper can be further revised to bring a commercial protocol and other aspects if the Concept and certain practical benefits mentioned herein interests the Authority.

P.S: Comments, suggestions or feedback are welcome at mb@projetoconsulting.com addressing to Mehul Bhandari, Telecom Consultant.

Consultant has broad experience in Telecommunications and Policy sector; holds Lisbon MBA from MIT Sloan School of Management| Catolica |Nova (in Boston, USA and Lisbon, Portugal); MSc (Mobile & Personal Communications) from King's College London and B.E in Electronics & communications from MIT- Mandsaur.

The Consultant had attended 26th August, 2013 OHD on Spectrum and likewise attended all the three days of 2009 OHD on Spectrum Management.