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Applying Thought

COGNITIVE RADIO

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Cognitive Radio

In today's world, use of wireless devices has increased significantly with the advances in wireless technology. In the near future significant growth of connected devices is expected with mass adoption of IoT. Huge amount of spectrum is required to support this increasing number of wireless devices. But the spectrum available is a scarce resource. If we check current spectrum allocation chart, it's very hard to find free spectrum to support upcoming volumes of wireless devices and mobile data traffic.

Cognitive Radio is a concept introduced to attack the upcoming spectrum crunch issue. Cognitive Radio users are unlicensed users who find unused licensed spectrum dynamically for its own use without causing any interference to licensed users.

Some of the existing techniques used in Cognitive Radio include spectrum sensing, spectrum database and pilot channel. These techniques are either complex that requires high computational power to detect unused spectrum or fail to capitalize on spectrum space created in real-time.

This white paper explores the merits and demerits of existing cognitive radio solutions and offers a view on how to solve these challenges.

Cognitive Radio Explained

Spectrum allocation typically happens through a licensing process. However, many parts of licensed spectrum are not optimally utilized. Figure 1 shows spectral inefficiency where certain bands are overcrowded while other bands are relatively unused.

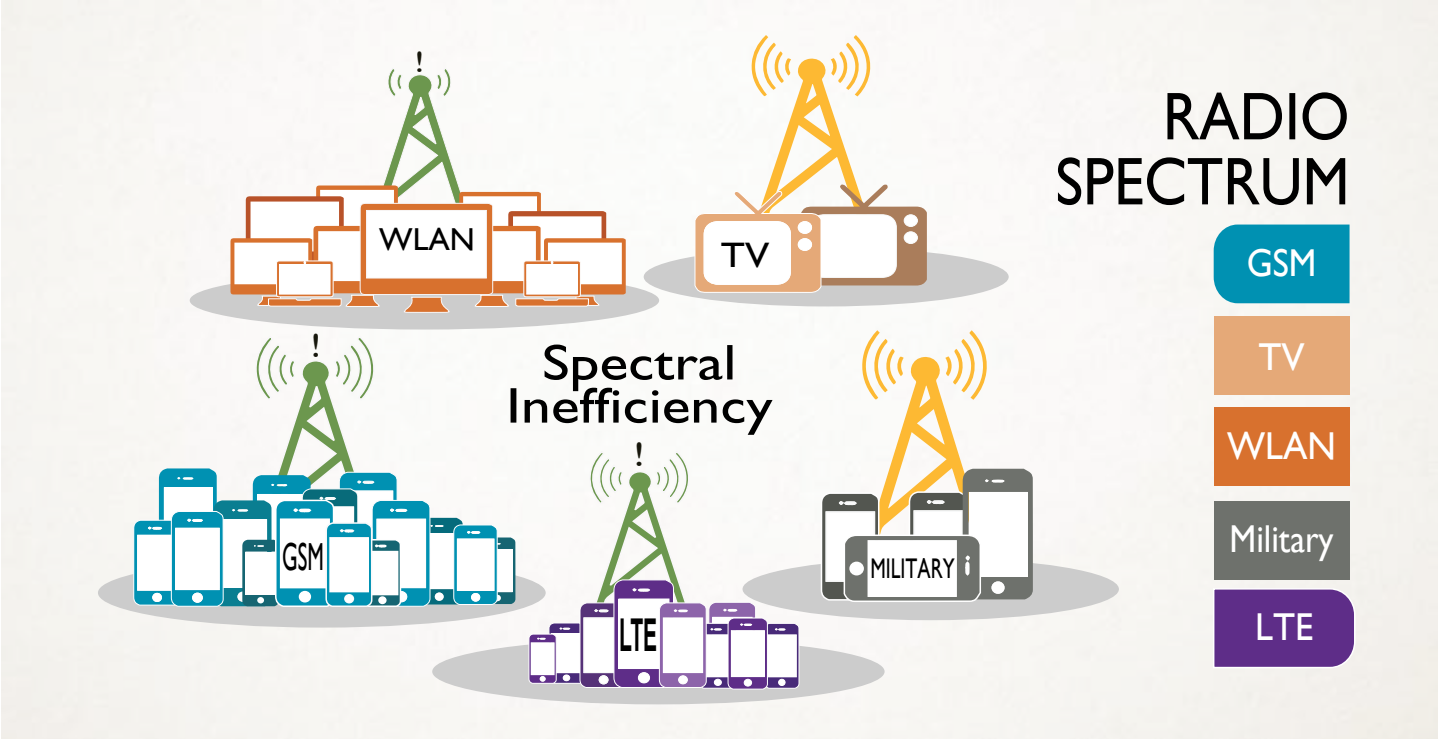

Figure 1: Spectral Inefficiency Explained

Cognitive radio (CR) is a form of wireless communication in which a transceiver can intelligently detect which communication channels are in use and which are not. It instantly moves into vacant channels while avoiding occupied ones. It does not cause any interference to the licensed user. Figure 2 shows a way of spectrum sharing.

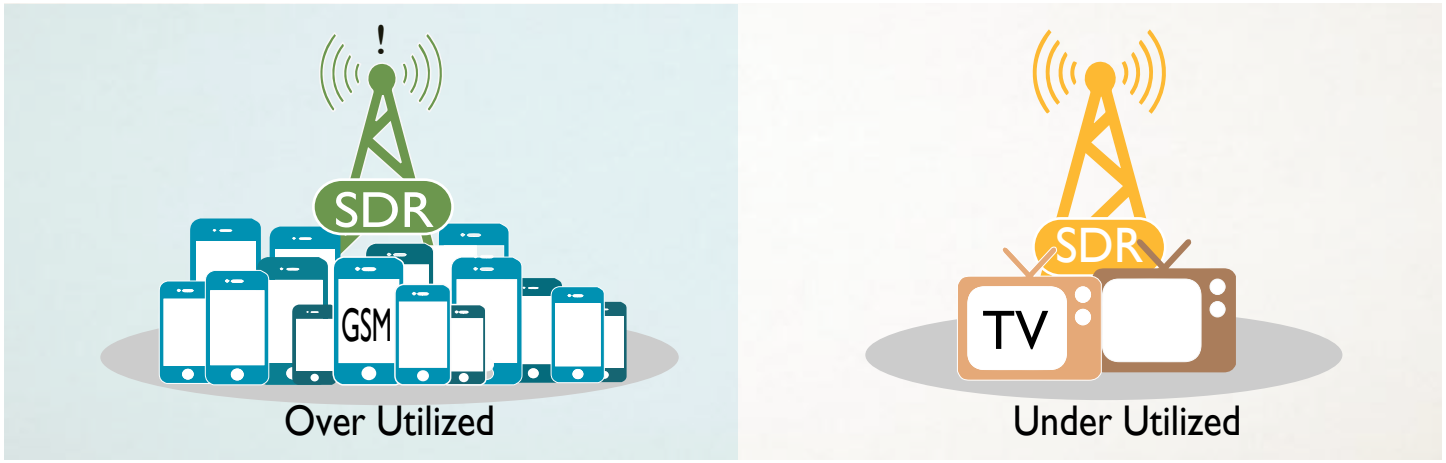

Figure 2: Overutilization and Underutilization of Licenses Spectrum

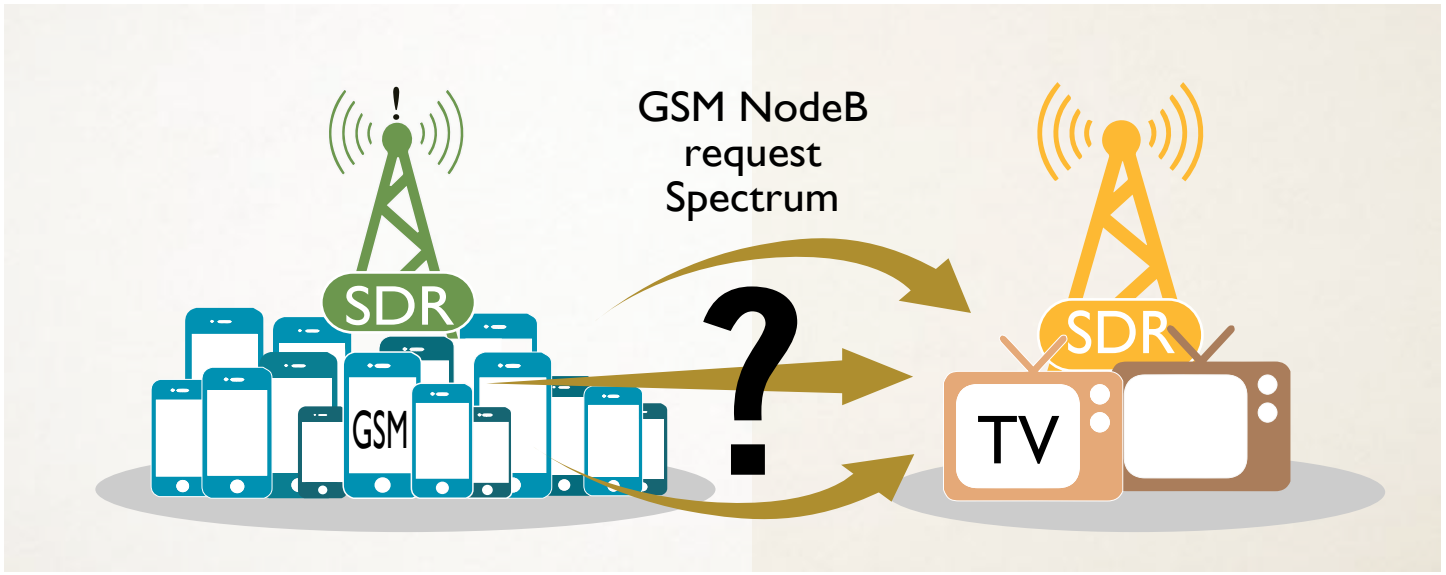

Figure 3: Spectrum Negotiation between two Spectrum Bands

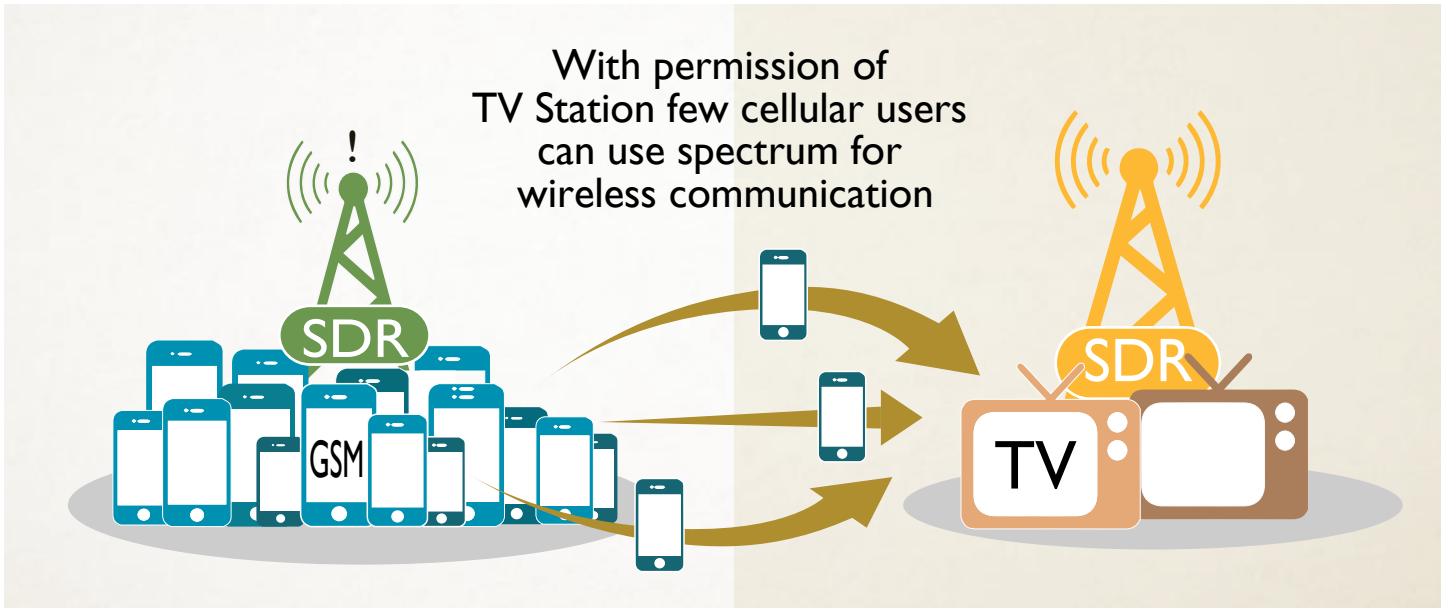

Figure 4: Usage of Underutilized Spectrum by Unlicensed User

Existing Cognitive Radio Techniques

Here are some existing techniques used in cognitive radio.

Technique 1 - Spectrum Sensing

CR devices closely track all the spectrum bands located in the neighborhood to identify its various primary users[1] and spectrum holes[2].

Widely used techniques for spectrum sensing are summarized in the below diagram.

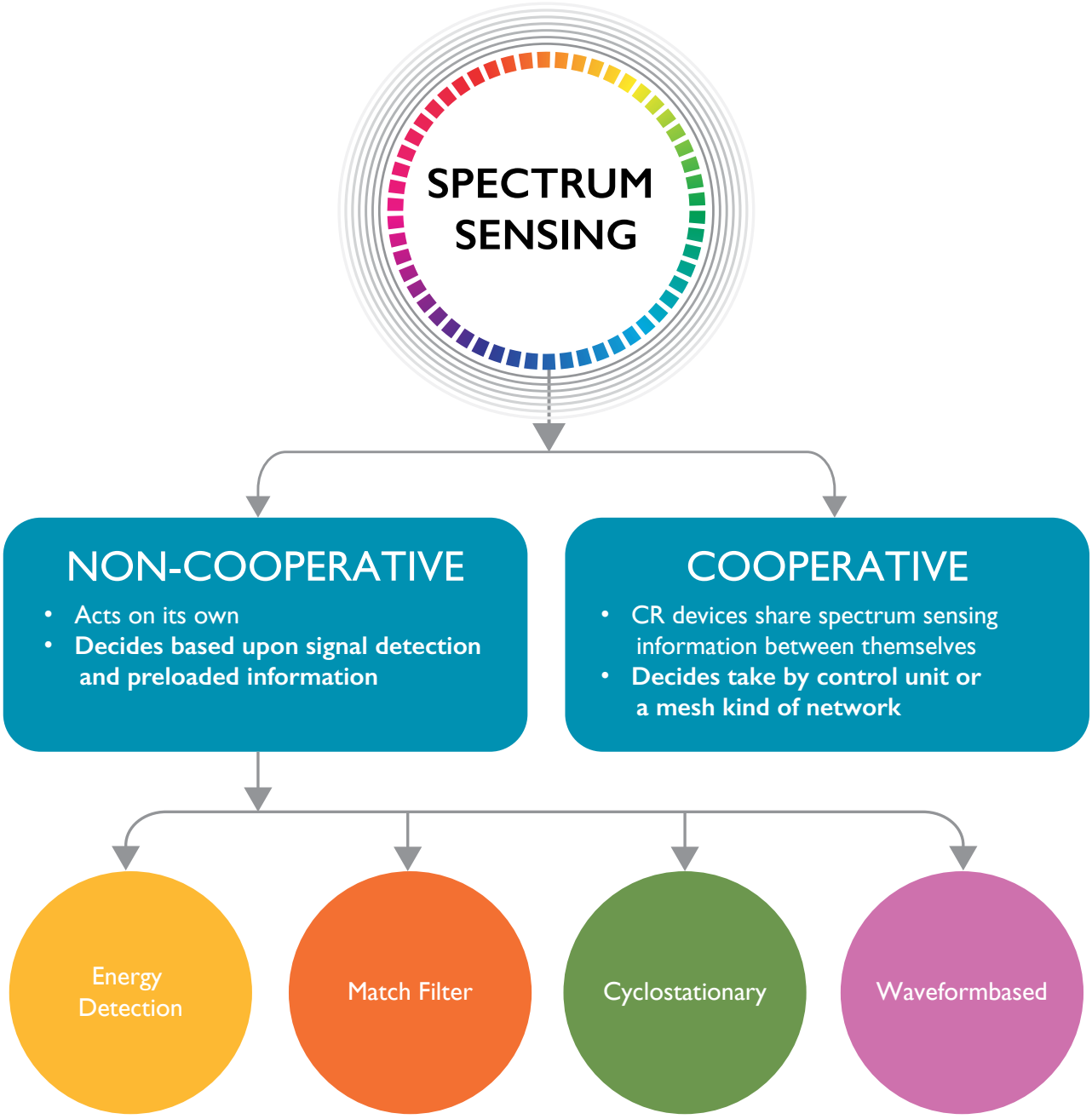

Figure 5: Spectrum Sensing Technique

[1] Primary users are the users who are licensed to operate in a particular spectrum band.

[2] Spectrum holes are space available in a spectrum band that can be utilized by unlicensed users. Spectrum holes are created and removed dynamically in real-time.

Limitations of Spectrum Sensing Technique

Spectrum Sensing is a best CR solution but it requires a large amount of sensing time. It also requires a complex algorithm to achieve reliability.

Non-cooperative:

PARALLEL SENSING	SEQUENTIAL SENSING	WAVE FORM	MATCH FILTER	CYCLO-STATIONARY
• Hardware Complexity • High Cost	• Long sensing time as CR devices have to scan the frequencies of primary users one by one to detect availability of spectrum holes	• Requires prior knowledge of synchronization signature of all primary users in various spectrum bands • This technique is susceptible to synchronization errors which can cause false detection of primary users	• Requires prior knowledge of waveform patterns of all primary users in the various spectrum bands • Noise variance and uncertainty makes this technique unreliable as CR devices are unable to detect transmitted signal from primary users	• High computational complexity

Cooperative:

Cooperative sensing technique needzzs to intelligently combine inputs from various CR devices and ascertain the availability of spectrum holes. The accuracy of the algorithm is critical here as incorrect detection can inversely affect the performance of primary users in spectrum bands. Designing such a 'perfect algorithm' is a challenge.

Technique 2 - Spectrum Database

Federal Communications Commission (FCC) proposed a spectrum database concept to remove complexity of spectrum sensing technique and to use TV white space. All TV stations need to update their next week usage in database maintained by FCC. CR devices can seek free spectrum information from this database. CR devices will have knowledge about free spectrum for use and can negate the need for complex sensing which requires time and money.

Limitation of Spectrum Database Technique

A significant percentage of spectrum holes are created dynamically for a short duration of time. It is very difficult for a database to update dynamic and real-time activity in spectrum. This presents a massive opportunity loss for CR devices (especially in the IoT ecosystem where several devices need to transmit a small amount of information which can be effectively done on dynamically created spectrum holes).

A Consolidated Approach to Drive CR

Efficient use of spectrum is necessary to support the growing number of Massive IOT devices. Unused spectrum can be available in large portions (such as TV white space) or as spectrum holes. Depending on needs and in an opportunistic method both white space and spectrum holes need to be used to satisfy future spectrum requirement. A combined approach could prove ideal for CR solution to meet the massive spectrum demands.

An easy to access local database (maintained in network component) and spectrum sensing technique in CR device can give a better solution for Cognitive Radio. The database should contain below information.

- Primary user's real-time usage (in term of frequency, time, space, transmission characteristics)
- History of primary user's usage pattern in that region in term of frequency, time, power, transmission characteristics

Benefits

A. Quick and accurate detection of unused spectrum

Any CR device can start searching spectrum holes which are indicated in the database. If database shows some real-time spectrum holes then CR devices can directly start using it otherwise from the historic information it can understand Primary User's usage pattern in that region and start spectrum sensing to find out the spectrum holes. As the CR device knows about primary signal characteristics in a particular time from database, spectrum sensing can be less complex, accurate and less time consuming.

B. Optimized search and lower battery consumption

By combining information from the database, history of primary user's usage patterns and signal characteristics of primary users, CR devices need not search the entire spectrum for availability but can rather zone in on a particular region. This process will save time and battery consumption.

Conclusion

The consolidated approach highlighted in this paper can help create less complex, cost effective solution. It can drastically reduce operator's investment as CR use unlicensed spectrum. As the IoT phenomenon grows, tens of billions of devices will need to communicate with each other in real-time. The highlighted CR approach will help operators cater to massive spectrum requirements and help build a connected world.

About the Author

Niladri Shekhar Paria is an industry expert in the Cellular Wireless connectivity domain and currently works as a Lead Architect in Wipro Technologies. He has over 10 years of experience in the wireless telecom industry in WCDMA, TD-SCDMA, GSPS (Satellite Phone Standard) modem software development for mobile devices, and WiMAX software development for base station.

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