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Multi-Antenna Spectrum Sensing using Bootstrap on Cognitive Radio for Internet of Things Application

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Abstract*: Cognitive Radio (CR) is a technology used for other developing technologies like Internet of Things (IoT), one part of CR is spectrum sensing which is useful as an empty spectrum searcher. The use of spectrum is now considered very minimal and raises the problem of scarcity of spectrum. But after testing the real problem is the spectrum in utilization. This problem can be overcome by using efficient utilization of CR technology using Spectrum Sensing. Sensing algorithms that are usually used such as: a suitable filter, energy detector and cyclostationary are not enough because there are many antennas to be detected. In the case of multi-antenna detection, research usually uses the Generalized likelihood ratio test (GLRT) approach. The GLRT Approach Detector also has three types of detectors, type-3 detectors do not determine statistical tests. However, if you use monte carlo or the literacy algorithm, you need a lot of data to get the detector performance. this research will combine algorithms using bootstrap to determine detector performance using small data because using Bootstrap basically only requires a small resampling. The research wants to show if a type-3 detector can help the detector produce good probabilities using little data. The expected result is that the GLRT approach can be combined with a bootstrap for type-3 detectors such as: arithmetic and geometric statistical tests (TAGM) and GLRT time code space code statistical tests (TSTBCGLRT) to help determine assumptions P_d assumptions. Then an experiment was carried out to determine the threshold, by comparing bootstrap with monte carlo, research is expected to show that bootstrap works without a known H_0 distribution and set the same threshold at all times.

Index Terms*: Bootstrap, Cognitive Radio, Multi-Antenna.

I. INTRODUCTION

The demand for wireless traffic is increasing, especially with internet of things (IoT) trends. According to previous research utilization is between 25% and 85%. Therefore it can increase wireless traffic using maximize spectrum utilization, one of a solution to increasing wireless traffic is efficient of the spectrum, the technology can make efficient is Cognitive Radio. Cognitive Radio has 4 spectra such as spectrum sensing, spectrum management, spectrum mobility, spectrum sharing [1], [2].

Spectrum sensing used to find an unoccupied channel and occupied channel in which if unoccupied channel it means channel include noise or there is no primary user (PU) and if occupied channel it means channel include noise and signal or there is PU [3], Secondary User (SU) can fill the channel. But, the problem is many SU needs an unoccupied channel or assumed multiantenna receiver [4]

In multi-antenna detection according to previous research usually using GLRT Approach [4]-[7]. According to previous research there are kind of type detector (generally GLRT Approach), Especially for detector type-3 that can not derive distribution H_0 and H_1. According to previous research signal processing can combine with bootstrap. Without, know about distribution H_0 and help for detector type-3 to get assumption Probability Detection (P_d). Therefore, using bootstrap for several detectors in this paper [7]-[8].

Bootstrap use resampling to develop the algorithms for spectrum sensing, it includes resampling in fixed sample size testing. In this research, bootstrap-based test sampling is used with a small sample size when the designed asymptotic test statistics fail. and bootstrap resampling is the right choice to reduce the problem of statistical distribution that is difficult to process. These bootstrap properties are explored to achieve the objective of developing spectrum sensing algorithms with a short sensing time [7]. the use of bootstrapping for applications of signal processing methods can be found in [9] and other references. This method has also been successfully applied in some research [9]-[10]. Literature about bootstrap implementation in rare spectrum sensing. In previously research, parametric bootstrapping is used to produce a likelihood ratio test distribution under the null hypothesis. Some research suggest using the bootstrap approach in multi-antenna spectrum sensing that is based on eigenvalue distributions, which have seldom been analyzed in previous adoption studies[11]. There are two kinds of algorithms including the type-3 that will be analyzed, Such as test statistic arithmetics and geometric (TAGM) and TSTBCGLRT. Assuming space-time block code (STBC) as PU and Geometrically-Based Single Bounce (GBSB) as multi-antenna channel [12]-[14].

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II. DETECTION MODEL

The multi-antenna concept is used because of the many user access from various devices. So much of the research that assumes a decline in methods with multi-antennas is shown in Figure 1:

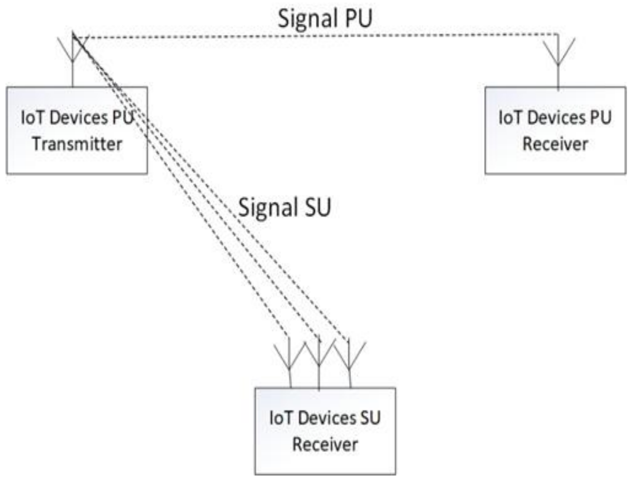


Figure 1 Multiantenna CR

Multi-antenna is usually used from 2 - 256, In this study, it was used from 2 to 32. In order to easily see the difference. By utilizing references [7] another decrease was used so that more accurate detection of one of the methods decreased using GLRT. Following is the equation of the GLRT approach model:

$$L_G(x) = \frac{p\left(x;\widehat{\theta}_1;H_1\right)}{p\left(x;\widehat{\theta}_0;H_0\right)} \quad (1)$$

Which in:

L_G = Comparison ratio of signal and noise probabilities
θ_1 and θ_2 = are some unknown parameters
$p(x;\theta_1;H_1)$ = is the probability of the signal
$p(x;\theta_0;H_0)$ = is the probability of the noise

L_G where the probability results in making a new algorithm, θ are components that can be loaded with certain parameters.

A. TAGM Algoritm

This one method detector type-3 is used in multi-antenna when the correlation matrix of the signal receiver in the form of Full-Rank [4].

$$TAGM = \frac{\frac{1}{M}\sum_{m=1} \lambda_{m.x}}{\left(\prod_{m=1} \lambda_{m.x}\right)} \quad (2)$$

Which in:

TAGM = The ratio of the sum of the eigenvalues and the multiplication of eigenvalues.
M = Number of multi-antennas.
λ = Eigenvalue of the correlation matrix
m = column matrix.
x = matrix line.= matrix line.

B. TSTBCGLRT Algoritm

This algorithm is used when the assumption of the coming signal is STBC [13]. Using the GLRT approach, the equation is obtained:

$$TSTBCGLRT = \frac{\lambda_{(\max)}}{tr(\psi)}$$
$$\lambda_{(\max)} = \frac{1}{l}\sum_{i=0}^{l}\delta_i \quad (3)$$
$$\psi = \frac{1}{K}\sum_{k=0}^{K}\delta_i$$

Which in:

TSTBCGLRT = Ratio of maximum eigenvalues to the diagonal sum of the correlation matrix
λ (max) = Maximum eigenvalue
ψ = Sum between diagonal matrices
l = Number of columns
K = Number of diagonals

C. Bootstrap Model

Bootstrap can be used at detector type-3 Detector type- 3 cant determine test statistic H_0 and H_1 from derivation. Because it, detector type-3 just only using monte carlo to find performance.

The sensing method is mostly applied based on the assumption that the sample size is very large, where the distribution of test statistics can be approached asymptotically. However, when using small or very small sample sizes in test statistics, the results of a statistical distribution can deviate very significantly from a predetermined distribution. This results in, spectrum sensing performance in terms of probability of false alarms or bad error detection. In this case, a small sample method, bootstrap, is proposed. Unlike the asymptotic test, the bootstrap approach shows the right balance between the probability of false alarms and error detection.

Furthermore, the advantage of the bootstrap method is easy to realize. It is because bootstrap can work without know about distribution H_0. Bootstrap is only use resampling the exist data in the signal. After that comparing between test statistical data with test statistical bootstrap data.

A bootstrap sample $x*=(x1*,x2*,x3*,......xn*)$ were obtained with a random sample of n times, with a scrambler of the original data points x1; x2; x3. Randomization using uniform distribution, bootstrap used in TAGM and TSTBCGLRT.

III. SYSTEM MODEL

A. Simulation Parameter

Use the bootstrap process by using uniform distribution. The following figure (2) shows the application of the bootstrap:

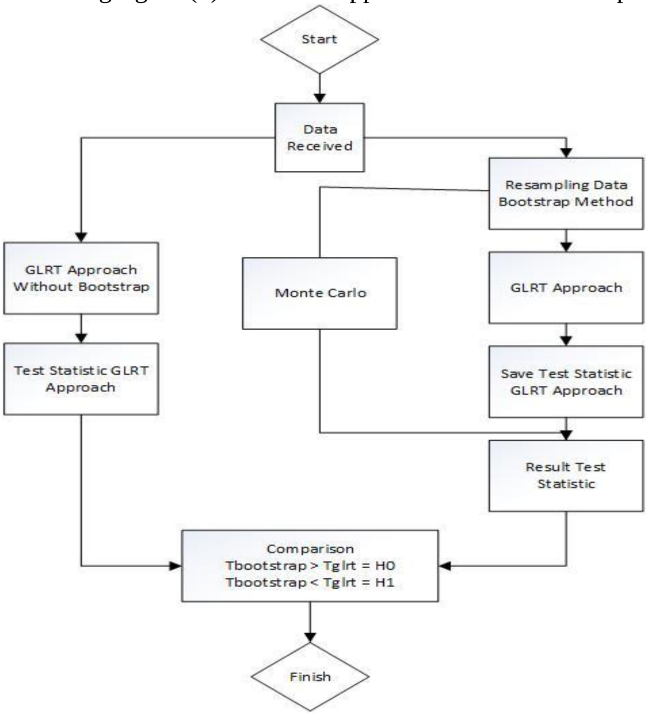
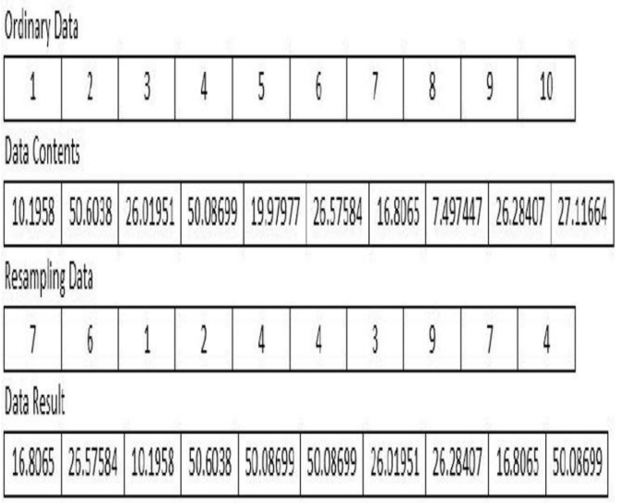


Figure 2 Flow Chart Detection

According to figure 2 the data received is then processed and divided into 2 parts. First, the data is entered into the GLRT approach without Bootstrap until it gets its new statistical value called TGLRT, the second the data enters the GLRT approach with bootstrapping repeatedly to get the Tbootstrap new statistical value as many as monte carlo runs compared to the results of the GLRT statistics without bootstrapping. The data is said to be H_0 if Tbootstrap is greater than TGLRT and vice versa.

Bootstrap methods used to overcome the problem of small sample amounts of data and also can help detector type-3. According to the figure (2) bootstrap is used to randomize the data by the rule random uniform distributed. Its method applied for a little number of a sample such as 10 and 20. For example, using Rx = 1 and the number of data is 10 N. The data matrix is 1x10, resampling the data sequence in figure (3):


Ordinary Data

1	2	3	4	5	6	7	8	9	10

Data Contents

10.1958	50.6038	26.01951	50.08699	19.97977	26.57584	16.8065	7.497447	26.28407	27.11664

Resampling Data

7	6	1	2	4	4	3	9	7	4

Data Result

16.8065	26.57584	10.1958	50.6038	50.08699	50.08699	26.01951	26.28407	16.8065	50.08699

Figure 3. Resampling Bootstrap (8)

Therefore, getting a new statistical test as many as monte carlo runs. After that, compared with the results of the Test Statistic GLRT. It is hoped this method can overcome the problem of sample size slightly and for detector type-3.

IV. RESULT

The simulation is divided into 3 parts as follows:

1) Analysis of increase bootstrap resample number for TAGM

2) Analysis of increase bootstrap resample number for TSTBCGLRT

3) Analysis of advantages Bootstrap from Monte Carlo Simulation using ROC curve to shows the performance of an algorithm, where the label y is Probability of Detection (P_d). Label x is Signal to Noise Ratio (SNR), a comparison of noise and signal energy. In this study using STBC as PU, GBSB as a channel that is Rayleigh distributed and set Pulse false alarm (P_{fa}) of 0.01.

A. Analysis of increase bootstrap resample number for TAGM

Adding resample numbers 10 and 20 used according to in [7]. Because the advantages bootstrap one of that is small of the number sample. Bootstrap can work resampling data as figure (2) The result in Figures (4) and (5) show that the number of sample bootstrap make greater P_d.

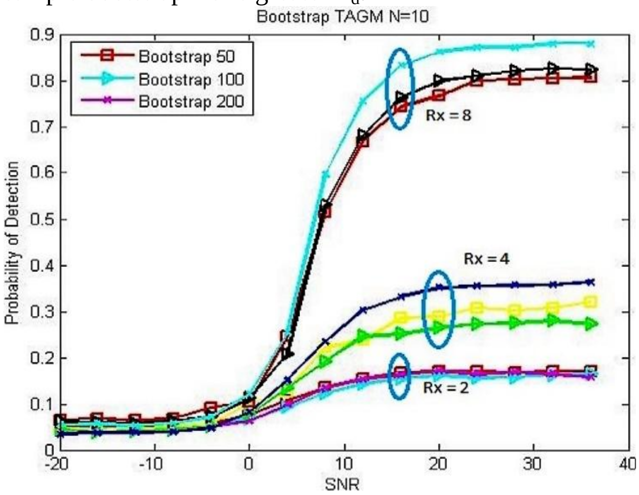


Figure. 4. ROC Curve Bootstrap TAGM with N=10

TABLE I RESULT RESAMPLING OF BOOTSTRAP FOR TAGM | VALUE IN P_d | N=10 | SNR = 10

Rx	Bootstrap 50	Bootstrap 100	Bootstrap 200
4	0.2	0.21	0.3
8	0.68	0.7	0.75

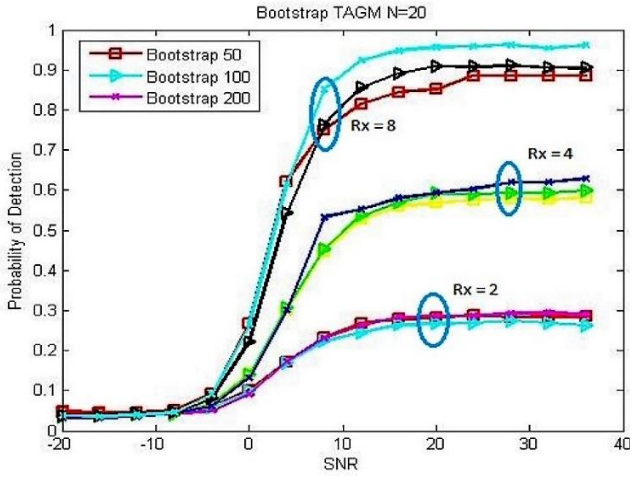


Figure. 5. ROC Curve for Bootstrap TAGM with N=20

TABLE II RESULT RESAMPLING OF BOOTSTRAP FOR TAGM | VALUE IN P_d | N=20 | SNR = 10

Rx	Bootstrap 50	Bootstrap 100	Bootstrap 200
4	0.5	0.53	0.56
8	0.78	0.83	0.9

According to table (I) and (II) which is implementation from figure (4) and (5) using Bootstrap 50 for Rx 4 (N=20) value P_d 0,5 is bigger than Rx 4 (N=10) value P_d 0,2, and also happens in Rx 8 (N=20) value P_d 0,78 is bigger than Rx 8 (N=10) value P_d 0,68. The simulation shows that the number of bootstrap samples is affected to increase the detector algorithm, one of them is because the nature of the GLRT decrease algorithm uses correlation so that more is better, another thing that is influential because a lot of resampling makes the bootstrap detector more precise to detect signals or noise according to [11] and [13].

B. Analysis of increase bootstrap resample number for TSTBCGLRT

Adding a resample number also did for TSTBCGLRT according to in [8]. Bootstrap can work resampling data as figure (2) The result in Figures (4) and (5) show that the largest bootstrap makes greater P_d.

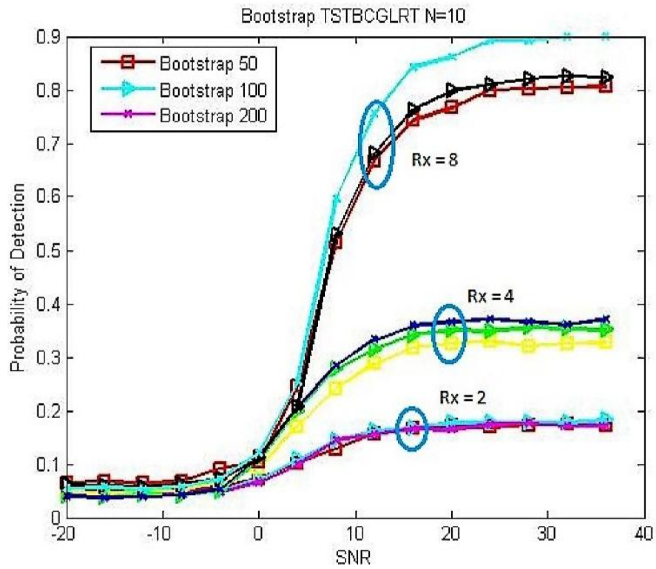


Figure 6. ROC Curve for Bootstrap TSTBCGLRT with N=10

TABLE III RESULT RESAMPLING OF BOOTSTRAP FOR TSTBCGLRT | VALUE IN P_d | N=10 | SNR = 10

Rx	Bootstrap 50	Bootstrap 100	Bootstrap 200
4	0.29	0.31	0.32
8	0.51	0.55	0.60

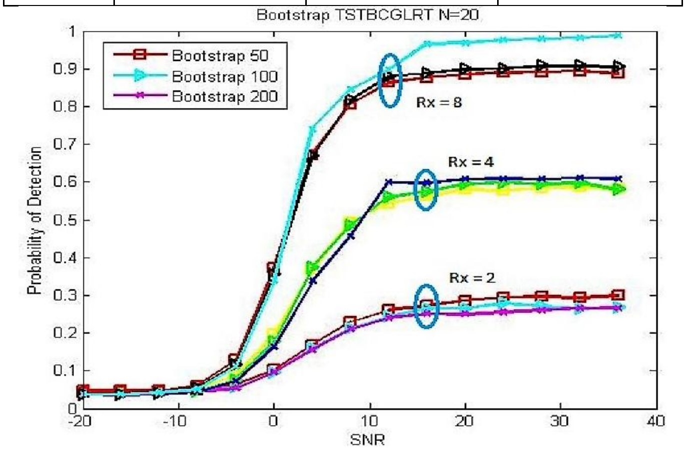


Figure. 7. ROC Curve for Bootstrap TSTBCGLRT with N=20

TABLE III RESULT RESAMPLING OF BOOTSTRAP FOR TSTBCGLRT | VALUE IN P_d | N=20 | SNR = 10

Rx	Bootstrap 50	Bootstrap 100	Bootstrap 200
4	0.51	0.52	0.58
8	0.81	0.83	0.86

According to table (III) and table (IV) which is the implementation value of figures (6) and (7) Bootstrap 50 for RX 4. (N = 20) the value of P_d 0.51 is greater than RX 4 (N = 20) value P_d 0.29, and also occurs at RX 8 (N = 20) P_d value of 0.81 and RX 8 (N = 20) value of P_d 0.51. Simulation shows that TSTBCGLRT is also influenced by the number of samples. The same thing as TAGM, TSTBCGLRT also influences correlation. The more input data the better the correlation. This is also because bootstrapping will work well if added with a large number of samples and resampling. when comparing table (III) and table (IV) with table (I) and table (II) the example takes TSTBCGLRT Bootstrap 50 for RX 4 (N = 20) P_d value of 0.51 is greater than value of RX 4 (N = 20) At 0.5 that means TSTBCGLRT is superior to TAGM, it happens because the signal assumption uses STBC, and it is suitable for TSTBCGLRT detectors.

C. Analysis of Advantages Bootstrap from Monte Carlo

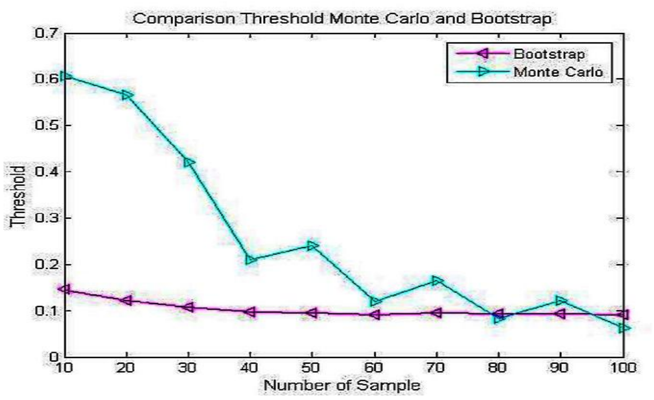


Figure 8. ROC Curve for Bootstrap 50 with N=20

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As in figure (8) Bootstrap has a fixed threshold in each sample amount better than if you use ordinary monte carlo. Where monte carlo always changes a number of thresholds. Bootstrap has a fixed threshold because resampling in bootstrap and this method can work without requiring H_0 information according to [11], so it can be explained if this method is suitable for other type-3 detectors.

V. CONCLUSION

One part of CR is spectrum sensing, which can maximize the use of frequency in IoT technology. There are many types of detection, one of which is used in multi-antennas is the GLRT Approach. The GLRT detection algorithm has several types, one of which is a type-3 detector. Where one of them is the TAGM and TSTBCGLRT detectors used in this study. One of the advantages of type 3 detectors is that they can use bootstrapping to maximize detection. This is used because bootstrapping can use very small samples. The results of the study used 3 analyzes, the first analysis showed that bootstrapping can also be influenced by the amount of sampling and the amount of input data. This is influenced by the nature of correlation between data. First and second analysis also shows the TSTBCGLRT algorithm is better than TAGM from the point of view when adding the amount of N and the amount of resampling. This can happen because TSTBCGLRT is derived from a decrease in the same algorithm as the conditions in this study. Recent experiments show that this method can always place the same threshold in each sample. This happens because the bootstrap does not need H_0 data to determine the threshold.

REFERENCES

1. Derek T. Otermat, I.K., Otero, C.E.. Analysis of the fm radio spectrum for secondary licensing of low-power short-range cognitive internet of things devices. IEEE Access 2016;4:6681 – 6691.
2. Rendy, Buddhikot, M.M.. Understanding dynamic spectrum access: Models,taxonomy and challenges. IEEE International Symposium on New Frontiers in Dynamic Spectrum Access Networks 2011;1st:649 – 663.
3. Luciano Barros Tarik Benaddi, L.F.. A design method of cognitive overlay links for satellite communications. Advanced Satellite Multimedia Systems Conference and the 15th Signal Processing for Space Communications Workshop (ASMS/SPSC) 2018;9th:1 – 6.
4. Annamalai, A.. Energy detection of unknown deterministic signals in - and - generalized fading channels with diversity receivers. International Conference on Computing, Networking and Communications (ICNC) 2014;1st:761 – 765.
5. Ayush Kumar Saumya Dwivedi, A.K.J.. Glrt-based spectrum sensing for mimo sc-fdma cognitive radio systems in the presence of synchronization impairments. IEEE Wireless Communications Letters 2016;1st:280 – 283..
6. Md. Tahidul Islam Muhammad Sajjad Khan, I.K.. Simo-based coarse fine sensing scheme for wideband cognitive radio communication. International Conference on Electrical and Electronic Engineering ICEEE 2015;26(3):205–208.
7. Fajar Nugraha Suhartono Tjondronegoro, F.Y.S.. Spectrum sensing of ofdm signals using glrt detector with bootstrap approach. International Conference on Telecommunication Systems Services and Applications (TSSA) 2015;9:1–6.
8. Suratman, F.Y.. Spectrum sensing in cognitive radio: Bootstrap and sequential detection approaches. Dissertation TU darmstadt 2014;1st.
9. Sidi Mohamed Hadj Irid, S.K.. A novel algorithm using spatial samplimg and bootstrap to estimate closed space doa for few samples. International Conference on Electrical Engineering - Boumerdes (ICEE-B) 2017;1st:1–5.
10. Kai Feng, L.L.. Source detection using bootstrap technique in spatial nonuniform noise. Fourth International Conference on Instrumentation and Measurement, Computer, Communication and Control 2015;1st:306 – 310.
11. Luo, , Meng, H.. Threshold estimation method for spectrum sensing using bootstrap technique. in Intelligent Computing Theories, Springer 2013;1st.
12. Toufik Mouchini Khalida Ghanem, M.D..A.Z.. Bootstrap approach for cognitive radio. International Conference on Smart Communications in Network Technologies (SaCoNeT) 2018;1st:155–158.
13. Teng Joon Lim Rui Zhang, Y.C.L., Zeng, Y.. Glrt-based spectrum sensing forcognitive radio. IEEE GLOBECOM 2008 - 2008 IEEE Global Telecommunications Conference 2008;1st:1–5..
14. Axell and Larsson, . Eigenvalue-based spectrum sensing of orthogonal space-time block coded signals. IEEE Trans Signal 2014;60(12).

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Mochammad Haldi Widianto is a lecturer at the Bandung Binus Creative Technology school. He obtained a bachelor's degree in Telecommunications and a master's degree in Telecommunications from Telkom University. Before becoming a lecturer, he was a technician at LIPI as well as a consultant at the Indonesian KOMINFO ministry. He has handled various problems at KOMINFO, especially at the Monitoring Center and resolved them as a consultant. In the field of education he has conducted research in various fields, especially in the field of telecommunications networks. His teaching experience for undergraduate students is in the fields of biostatistics, neural networks, mathematical modeling and signal processing. Now he is based in Bandung and resides there

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