Non-parametric Spectrum Sensing based on Censored Observations in Quasi-static Fading Channel for Cognitive radio

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Outline

1. **Background**
   - Opportunistic Spectrum Access
   - Related work
   - Goodness of fit (GoF) based Spectrum Sensing
   - Concept of Censoring

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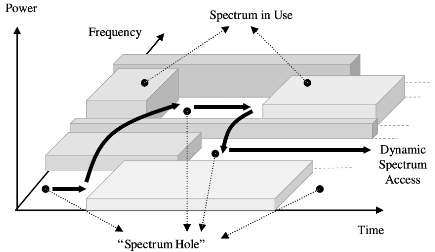
7. **Conclusion**

- The underutilization of spectrum opens up the opportunity to identify and exploit spectrum holes using Opportunistic Spectrum Access (OSA)
- **Spectrum hole:** A band of frequencies assigned to a PU,but at a particular time and specific geographic location, the band is not being utilized by that user [Haykin 2005].



- A promising mechanism to improve the spectrum utilization by exploiting the spectrum holes is based on the **COGNITIVE RADIO** technology.

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    - Cyclostationary feature detection, Waveform based sensing etc.
3. **Non-parametric: Realistic situation**
    - The knowledge of primary users is limited and incomplete
    - If assumption about parameter related to the know pattern is invalid or not accurate,than, the performance will deteriorate fast

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  6. Student's t-test

- In statistics, engineering, economics, and medical research, censoring occurs when the value of a measurement or observation is only partially known.
- If some observations $X_1, X_2, \ldots.X_n$ of a random sample are missing, the sample is said to be censored.
- Censoring is when an observation is incomplete due to some random cause. The cause of the censoring must be independent of the event of interest if we are to use standard methods of analysis.
- Examples of censored data: Survival Analysis

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3. Person-C: takes part in the study until time TC . She then is hit by a car and dies. Her survival time with regard to the event of interest, namely death through lung cancer, is also censored: we know it is at least TC

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5. **Type-2 censoring:** Censoring may occur for fixed value than it is called as Type-2 censoring.
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- If the experiment is continued for a fixed time t, the number of items which fail in that time would be random variable and the censoring would be Type-1 censoring.
- If the experiment is continued until 20 items have failed, then r is a fixed at 20 and we have Type-2 censoring.
- We have used concept of **Type-2 Right Censoring** for developing new spectrum sensing method

Following are the key reasons to utilize the concept of censoring in Cognitive radio based spectrum sensing methods :

1. For reducing an error at low SNR, Lower number of observations:
   - All types of GoF based sensing methods which are proposed in literature so far, have used all observations to determine ECDF.
   - However, the distance of the CDF and ECDF is higher especially at the right tail due to less number of observations.
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Where, $F_Y(y)$: Empirical distribution Function

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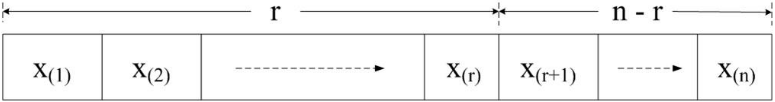
- Here, We have used Type-2 right censoring: As shown in next figure



- Now, we retain first r observations and drop or censor the last $n-r$ observations as shown in Figure.
- Hence, x_r is the highest valued observation.
- This method of censoring $n-r$ highest valued observations is known as right censoring with Type-2.

System Model

- Constraints : Quasi static fading channel
- The local observations at the cognitive when there is signal transmission radio can represented by Model,

$$Y_i = \sqrt{\rho} hs + W_i, i = 1, 2, 3...n$$

Where,

h :The fading factor (Quasi-static rayleigh fading)

s :The transmitted signal (s = 1)

W_i:The Gaussian noise with zero mean and unit variance

ρ :The Received SNR

System Model (Cont.)

- When there is no PU signal transmission,

$$H_0 : Y_i = W_i$$

and

$$F_0(y) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{y} e^{\frac{-x^2}{2}} dx$$

- When there is PU signal transmission,

$$Y_i = \sqrt{\rho} hs + W_i, i = 1, 2, 3 \ldots n$$

and

$$F_1(y) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{y} e^{\frac{-(x-\sqrt{\rho}hs)^2}{2}} dx$$

- For CAD sensing, we use modified Cramer-von Mises GoF statistic to measure distance between $F_X(x)$ and $F_0(x)$.
- Based on the asymptotic distribution of censored observations, statistic can be expressed as,

$$_{q,p}A_n^2 = n\int_q^p \frac{(F_n(x) - F_0(x))^2}{F_0(x)(1 - F_0(x))} dF_0(x), \quad 0 \le q < p \le 1,$$

where p denotes censoring ratio which can be expressed as

$$p = \lim_{n\to\infty} \quad \frac{r}{n}.$$

- Here, we take $q = 0$. In this case, statistic can be written as,

$$_{p}A_n^2 = n\int_0^p \frac{(F_n(x) - F_0(x))^2}{F_0(x)(1 - F_0(x))} dF_0(x)$$

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2. **Step:2** Sorting all the observations in ascending order, we get
$$x_1 \leq x_2 \leq \cdot\cdot \leq x_r \leq x_{r+1} \leq \cdot\cdot \leq x_n,$$
where $x_{r+1} \leq x_{r+2} \cdot\cdot \leq x_n$ observations are censored.

3. **Step:3** Calculate the required test statistic ${}_pA_n^2$ for the observations $x_1 \leq x_2 \leq \cdot\cdot \leq x_r$ defined as,

$$
{}_pA_n^2 = -\frac{1}{n}\sum_{i=1}^{r}(2i-1)(lnz_i - ln(1-z_i)) - 2\sum_{i=1}^{r} ln(1-z_i)
$$

$$
-\frac{1}{n}[(r-n)^2 ln(1-z_r) - r^2 lnz_r + n^2 z_r],
$$

where $z_i = F_0(y_i)$.

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4. **Step:4** If ${}_pA_n^2 > \lambda$, then reject null hypothesis H_0.

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5. **Step:5** Compute performance metric as Probability of Detection (P_d) with a given value of P_f.

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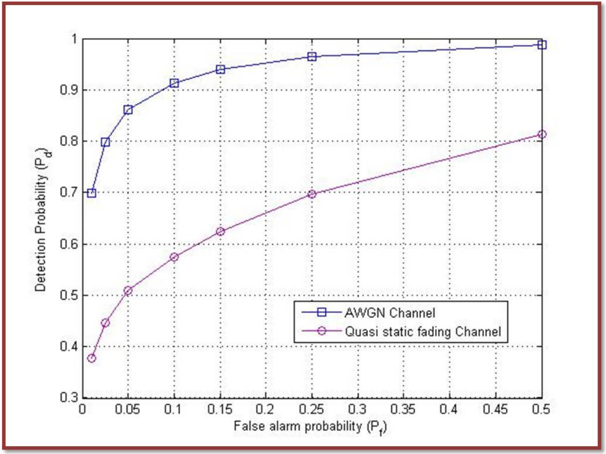
- In statistical term, P_f(Probability of False Alarm) corresponds to type I error and 1- Pd (Probability of Miss Detection) is type II error
- The probability of detection is defined as:

$$P_d = P(\Im > \lambda | H_1)$$

- The probability of false alarm is defined as:

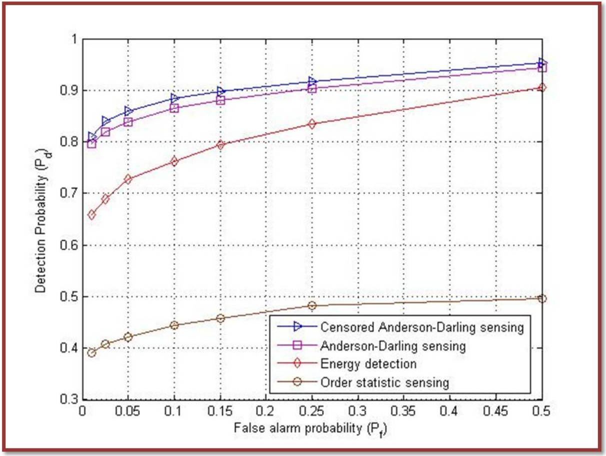
$$P_f = P(\Im > \lambda | H_0)$$

- The plot of P_d against P_f is called Receiver Operating Characteristic (ROC curve).

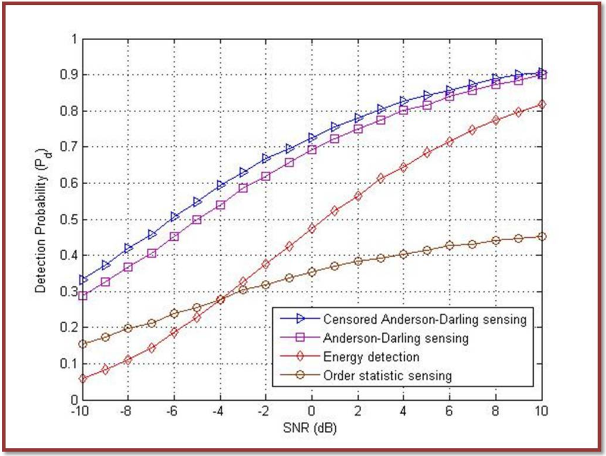


- ROC Curve for CAD sensing Algorithm under AWGN and Quasi static fading channel
- No. of observations
  N = 40, R = 24 , p= 0.6
- SNR = -2dB , Pf = 0.05
- Result : As expected

Major Work Contribution
-Simulation Results-2



- ROC Curve for CAD sensing Algorithm for Quasi static fading channel
- No. of observations N = 40, R = 24 , p= 0.6
- SNR = 6 dB , Pf = 0.05
- Result : Pd = 0.8615



- SNR vs. Pd
- No. of observations
  N = 40, R = 24 , p= 0.6
- SNR = 6 dB , Pf = 0.05
- Result : CAD sensing has almost 6 dB gain over ED sensing and 1 dB gain over AD sensing
- Below -4 dB SNR performance of ED degraded : As expected

Conclusion

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3. **OS sensing [K.Arshad,2012] :**
    - Performs better than AD and ED sensing at higher number of samples $N > 25$ under AWGN channel only

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   - Better than ED and OS sensing at lower SNR
3. **OS sensing [K.Arshad,2012] :**
   - Performs better than AD and ED sensing at higher number of samples $N > 25$ under AWGN channel only
4. **CAD sensing:**
   - The better detection performance is obtained using CAD sensing algorithm in comparison with AD, ED and OS sensing at lower SNR and observations
   - OS sensing performs poor under Quasi-static fading channel at low number of observations.

Thank you