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Interference Reduction In Sensing Mechanism Of Cognitive Radio Using Fuzzy Based Smartcity Technique

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Abstract

Cognitive Radio (CR) technology has emerged as a key solution to spectrum scarcity by enabling dynamic spectrum access through intelligent sensing and adaptive transmission. However, one of the major limitations of CR systems is the presence of interference in the sensing mechanism, which degrades detection accuracy, increases false alarms, and reduces overall spectrum utilization efficiency. This challenge becomes more critical in the context of smart city environments, where dense wireless communication networks coexist and demand reliable spectrum management. This study proposes an interference reduction framework for cognitive radio systems using a Fuzzy-Based Smart City Technique. The fuzzy logic controller is employed to intelligently evaluate uncertain sensing parameters such as signal-to-noise ratio (SNR), channel occupancy probability, and interference levels, thereby improving decision-making in dynamic spectrum allocation. By leveraging the adaptive capabilities of fuzzy logic, the proposed technique minimizes interference, enhances spectrum sensing accuracy, and ensures reliable connectivity across heterogeneous smart city networks. Simulation results indicate that the fuzzy-based smart city approach outperforms conventional sensing methods by reducing false detection rates, improving spectrum efficiency, and supporting seamless communication in complex urban environments. This research provides a robust pathway toward interference-resilient cognitive radio deployment in future smart city applications. The conventional Signal to noise ratio(SNR) that cause interference in the cognitive radio sensing mechanism was 8dB, On the other hand, when Fuzzy based smart city technique was incorporated into the system, it automatically increased to10.32dB and the conventional interference to noise ratio INR that cause interference in the cognitive radio sensing mechanism was6dB. Meanwhile, when Fuzzy based smart city technique was integrated into the system, it simultaneously reduced to5.3dB. Finally, with these results obtained, it definitely meant that the percentage interference reduction in sensing mechanism of cognitive radio when Fuzzy based smart city technique was integrated into the system was13.2%.

Keyword: Interference, reduction, sensing, mechanism, cognitive, radio, fuzzy, based, SMARTCITY, technique

1.0 Introduction

The rapid growth of wireless communication and the proliferation of smart devices in urban environments have placed unprecedented demands on the radio frequency (RF) spectrum. Traditional fixed spectrum allocation policies have proven inefficient, as many licensed frequency bands remain underutilized while unlicensed bands experience severe congestion (Haykin, 2005). Cognitive Radio (CR) technology has been proposed as a solution to this problem, enabling dynamic spectrum access by allowing secondary users to opportunistically utilize unused licensed frequencies without causing harmful interference to primary users (Akyildiz et al., 2006). A fundamental component of CR is spectrum sensing, which ensures accurate detection of spectrum availability and protection of licensed users. However, spectrum sensing mechanisms are often impaired by interference, multipath fading, shadowing, and noise uncertainty, leading to false alarms, missed detections, and inefficient spectrum utilization (Zeng & Liang, 2010). In the context of smart cities, where multiple wireless systems—including Internet of Things (IoT), vehicular communications, and public safety networks—compete for limited spectrum resources, the problem of interference in cognitive radio sensing becomes even more critical (Gharaibeh et al., 2017). Smart cities rely on seamless connectivity for applications such as intelligent transportation systems, e-health services, smart grids, and public surveillance, all of which demand reliable communication with minimal interference (Al-Fuqaha et al., 2015).

Therefore, interference reduction in CR sensing mechanisms is crucial to ensuring efficient spectrum sharing and supporting the sustainability of smart city infrastructures. To address this challenge, fuzzy logic-based techniques have been widely adopted due to their ability to handle uncertainties, approximate reasoning, and nonlinear system behavior without requiring precise mathematical models (Zadeh, 1996). Unlike conventional threshold-based sensing methods, fuzzy logic controllers can intelligently combine multiple input parameters such as signal-to-noise ratio (SNR), interference levels, and channel availability probability to make adaptive decisions in real time (Ejaz & Ibnkahla, 2013). Recent studies have demonstrated that fuzzy-based approaches significantly improve spectrum sensing accuracy and reduce interference in heterogeneous networks (Kaur & Sharma, 2020). Integrating fuzzy-based interference reduction techniques into smart city communication frameworks enhances spectrum efficiency, reliability, and resilience of cognitive radio systems. This research builds on the convergence of fuzzy logic and smart city technologies to propose an intelligent spectrum sensing framework that minimizes interference while supporting the high data demands of urban infrastructures. Consequently, it contributes toward the realization of sustainable, interference-resilient smart city communication networks.

2.0 Methodology

To characterize and establish the metric causes of interference in cognitive radio sensing mechanism

Table1 characterized and established metric causes of interference in cognitive radio sensing mechanism

METRIC	CAUSES OF INTERFERENCE	THRESHOLD VALUE	CONVENTIONAL CAUSES OF INTERFERENCE IN COGNITIVE RADIO SENSING MECHANISM
Signal to noise ratio(SNR)	low snr due to background noise and multipath fading	<10db	8 db
Interference to noise ratio(INR)	Co channel or adjacent channel interference	>5db	6 db

Spectrum occupancy probability	high channel usage by primary users	>0.6	0.7
Channel capacity under interference	reduced due to external signal	$<2\text{bit/s}$	1.6bit/s
Adjacent channel leakage ratio(ACLR)	power leakage into adjacent bands	$>-30\text{db}$	-32 db
high bit error rate	interference increases demodulation errors	$>10^{-2}\text{bits}$	0.8 bits
latency due to sensing delay	excessive sensing time increases collision	$>10\text{ms}$	12 ms

To design a conventional SIMULINK model for cognitive radio sensing mechanism

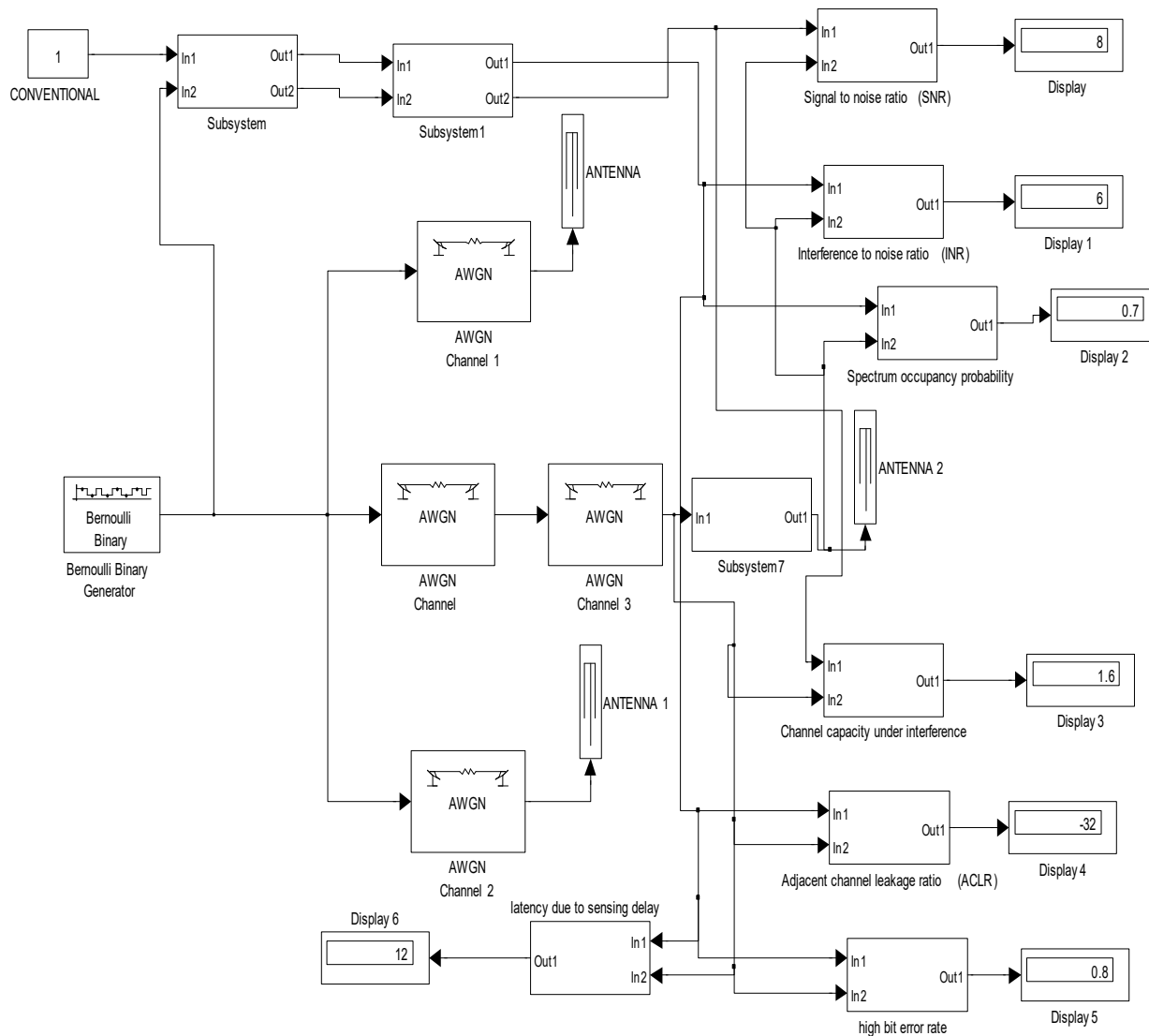


Fig 1: designed conventional SIMULINK model for cognitive radio sensing mechanism

The results obtained were as shown in figures 7 and 8

To develop a smart city rule base that would minimize interference in cognitive radio sensing mechanism

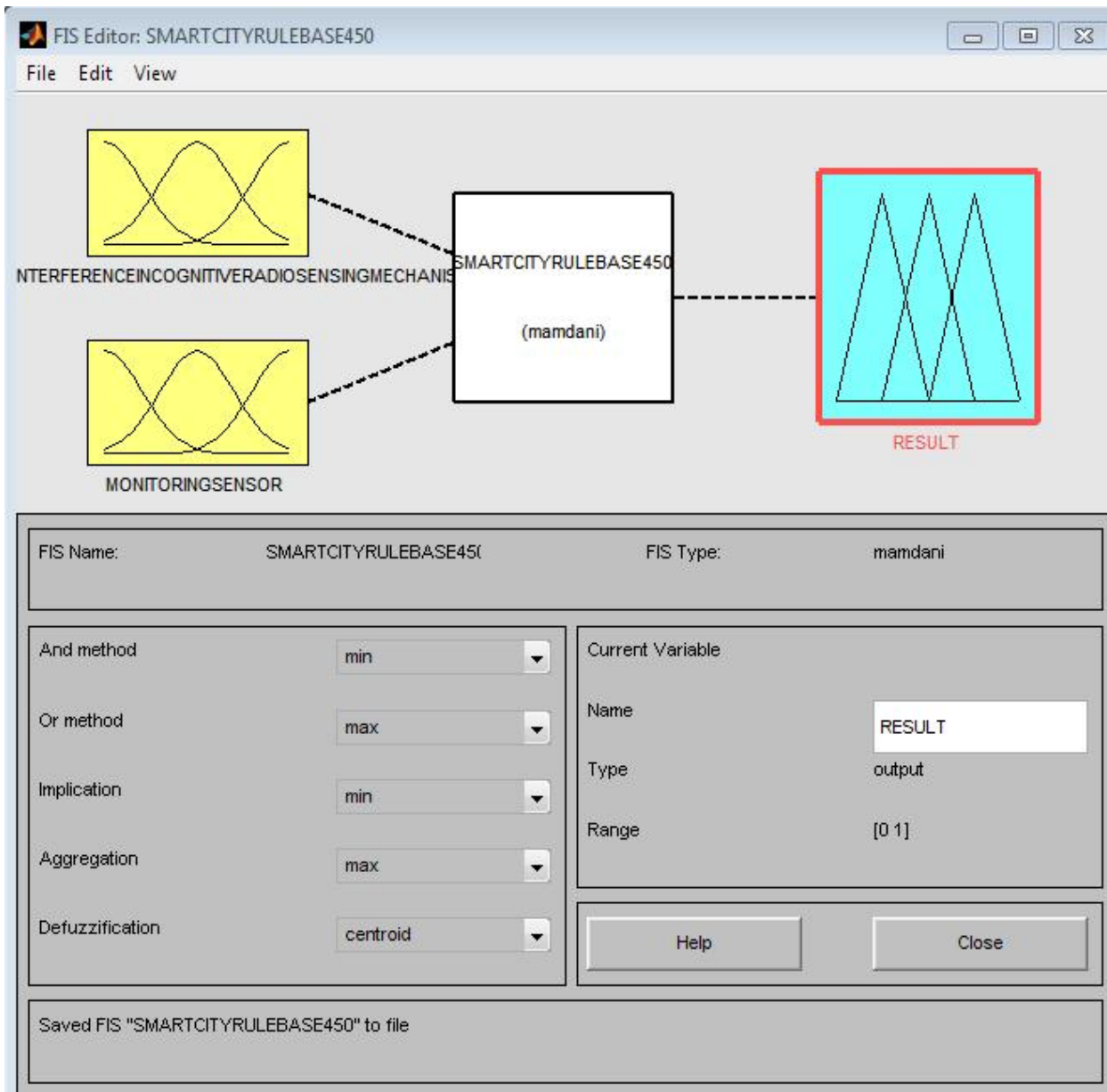


Fig 2: developed smart city fuzzy inference system that would minimize interference in cognitive radio sensing mechanism

This had two inputs of causes of interference in cognitive radio sensing mechanism and monitoring sensor. It also had an output of result.

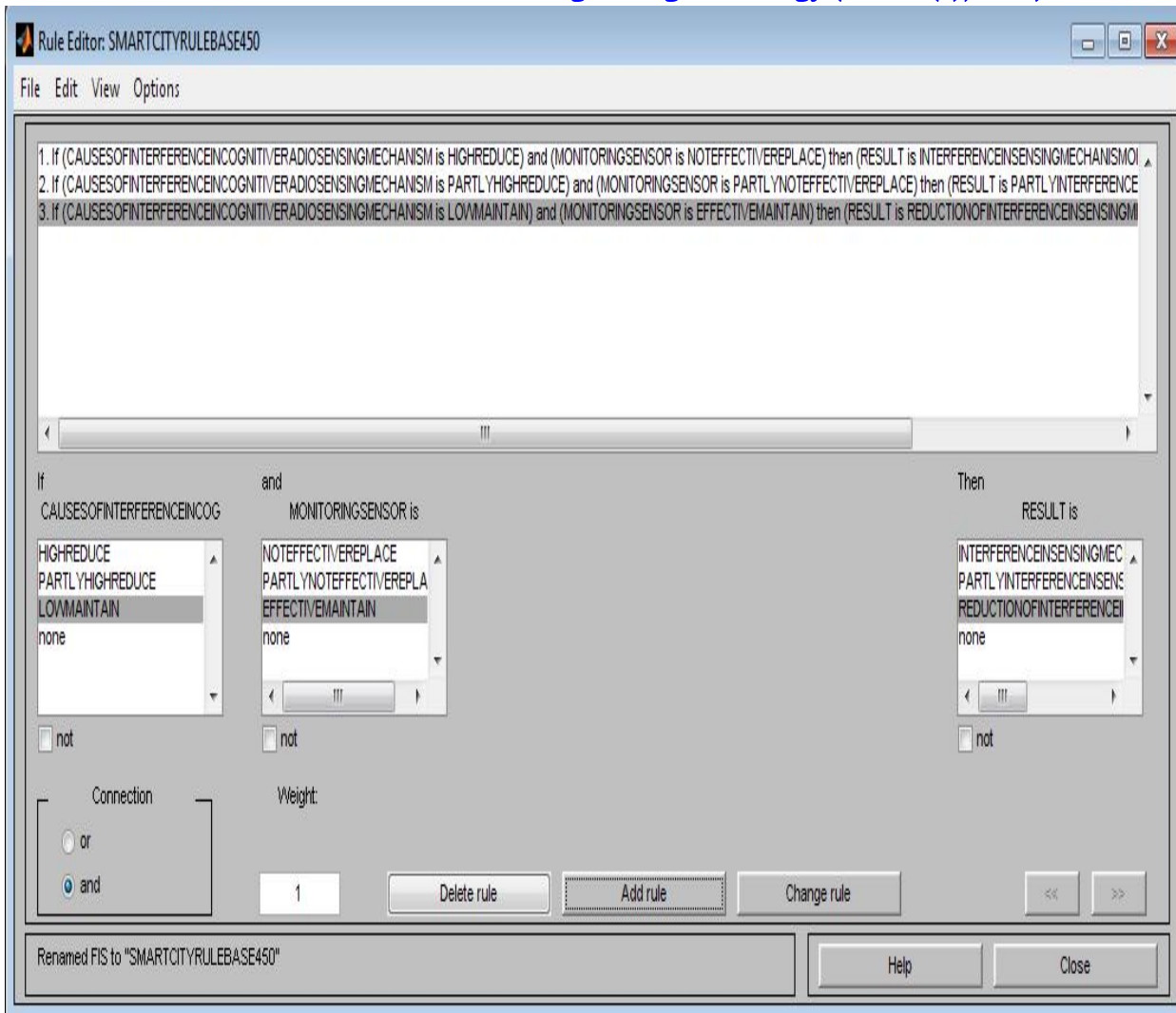


Fig 3: developed smart city rule base that would minimize interference in cognitive radio sensing mechanism

The detailed rules were as shown in table 2

Table 2: detailed developed smart city rule base that would minimize interference in cognitive radio sensing mechanism

IF CAUSES OF INTERFERENCE IN COGNITIVE RADIO SENSING MECHANISM IS HIGH REDUCE	AND MONITORING SENSOR IS NOT EFFECTIVE REDUCE	THEN RESULT IS INTERFERENCE INSENSING MECHANISM OF COGNITIVE RADIO
IF CAUSES OF INTERFERENCE IN COGNITIVE RADIO SENSING MECHANISM IS PARTLY HIGH REDUCE	AND MONITORING SENSOR IS PARTLY NOT EFFECTIVE REDUCE	THEN RESULT IS INTERFERENCE INSENSING MECHANISM OF COGNITIVE RADIO
IF CAUSES OF INTERFERENCE IN COGNITIVE RADIO SENSING MECHANISM IS LOW MAINTAIN	AND MONITORING SENSOR IS EFFECTIVE MAINTAIN	THEN RESULT IS REDUCTION OF INTERFERENCE INSENSING MECHANISM OF COGNITIVE RADIO

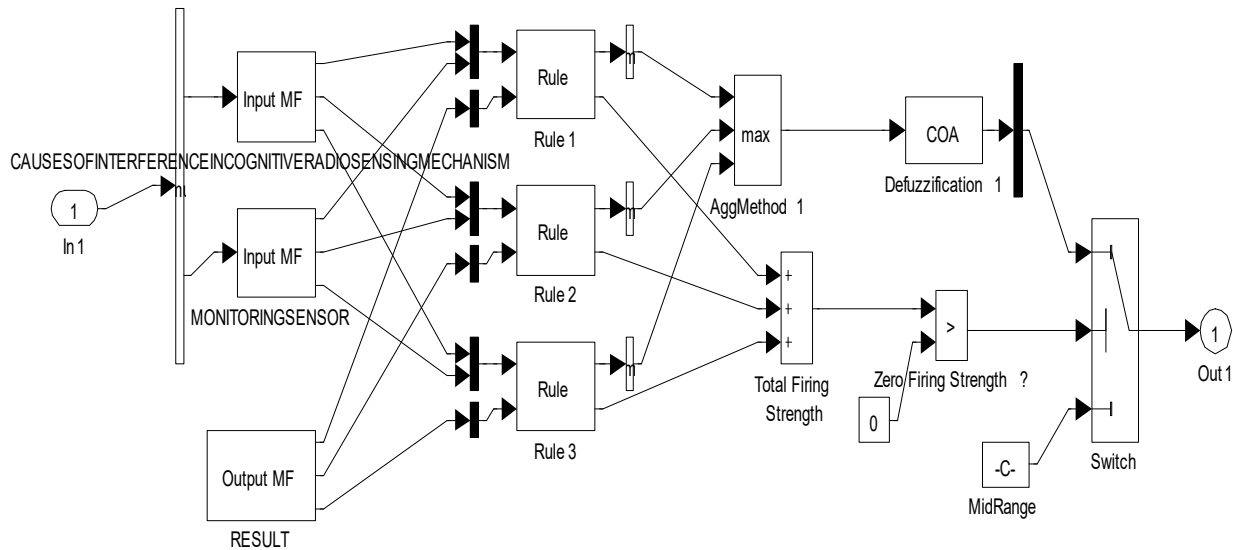


Fig 4: the operational mechanism of developed smart city rule base that would minimize interference in cognitive radio sensing mechanism

To design a SIMULINK model for smart city

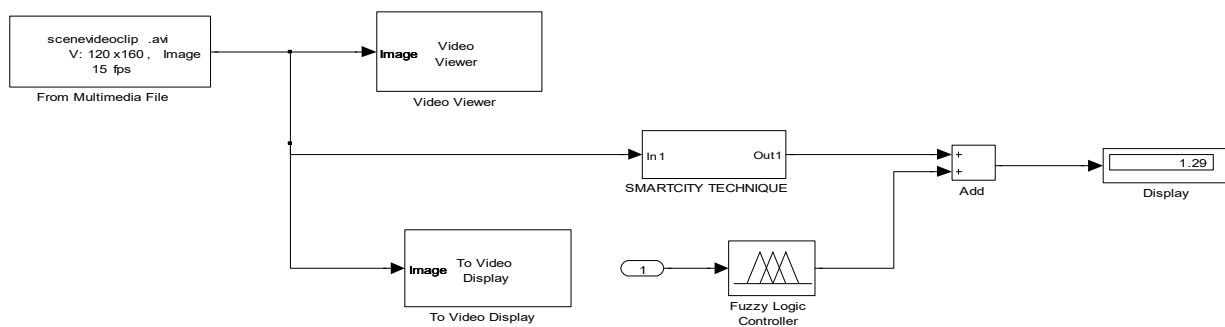


Fig 5: designed SIMULINK model for smart city

This would be integrated to the conventional SIMULINK model for cognitive radio sensing mechanism to enhance the efficacy of interference reduction in cognitive radio sensing mechanism

To develop an algorithm that would implement the process

- 1.Characterize and establish the metric causes of interference in cognitive radio sensing mechanism
- 2.Identify low signal to noise ratio(SNR)
- 3.Identify high interference to noise ratio(INR)
- 4.Identify spectrum occupancy probability
- 5.Identify channel capacity under interference
- 6.Identify adjacent channel leakage ratio(ACLR)
- 7.Identify high bit error rate
- 8.Identify latency due to sensing delay

9. Design a conventional SIMULINK model for cognitive radio sensing mechanism and integrate 2 through 8.
10. Develop a smart city rule base that would minimize interference in cognitive radio sensing mechanism
11. Design a SIMULINK model for smart city
12. Integrate 10 and 11.
13. Integrate 12 into 9
14. Did the causes of interference in cognitive radio sensing mechanism reduce when 12 was integrated into 9?
15. IF NO go to 13
16. IF YES go to 17
17. Interference reduction in sensing mechanism of cognitive radio
18. Stop
19. End

To design a SIMULINK model for interference reduction in sensing mechanism of cognitive radio using fuzzy based smart city technique

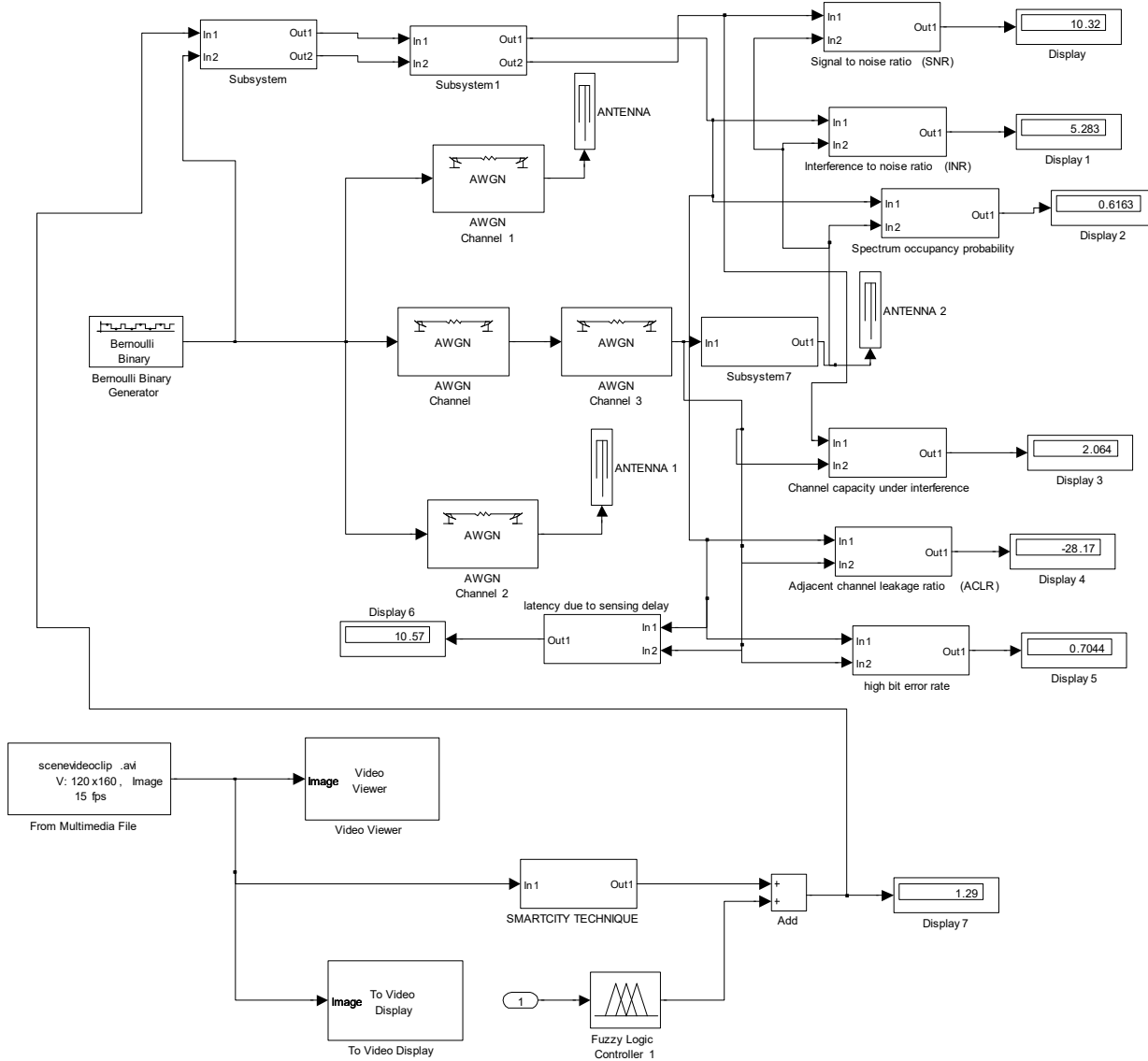


Fig 6: designed SIMULINK model for interference reduction in sensing mechanism of cognitive radio using fuzzy based smart city technique

The results obtained were as shown in figures 7 and 8.

To validate and justify the percentage improvement in the reduction of interference in the cognitive radio sensing mechanism with and without fuzzy based smart city technique

To find percentage improvement in Signal to noise ratio(SNR) cause of interference in the cognitive radio sensing mechanism

Conventional SNR =8 dB

Fuzzy based smart city technique SNR=10.32dB

%improvement in Signal to noise ratio(SNR) cause of interference in the cognitive radio sensing mechanism=

$$\frac{\text{Fuzzy based smart city technique SNR} - \text{Conventional SNR}}{\text{Conventional SNR}} \times 100\%$$

Conventional SNR

1

%improvement in Signal to noise ratio(SNR) cause of interference in the cognitive radio sensing mechanism=
 $10.32\text{dB} - 8 \text{ dB} \times 100\%$

$$\frac{10.32\text{dB} - 8 \text{ dB}}{8 \text{ dB}} \times 100\%$$

%improvement in Signal to noise ratio(SNR) cause of interference in the cognitive radio sensing mechanism=
 29%

To find percentage improvement in the reduction of interference to noise ratio(INR) cause of interference in the cognitive radio sensing mechanism

Conventional INR =6dB

Fuzzy based smart city technique INR =5.3dB

%improvement in interference to noise ratio (INR) cause of interference in the cognitive radio sensing mechanism=

Conventional INR-Fuzzy based smart city technique INR x 100%

$$\frac{\text{Conventional INR} - \text{Fuzzy based smart city technique INR}}{\text{Conventional INR}} \times 100\%$$

%improvement in interference to noise ratio (INR) cause of interference in the cognitive radio sensing mechanism= 6dB - 5.3dB x 100%

$$\frac{6\text{dB} - 5.3 \text{ dB}}{6 \text{ dB}} \times 100\%$$

%improvement in interference to noise ratio (INR) cause of interference in the cognitive radio sensing mechanism= 13.2%

3.0 Results and Discussion

Table 2: comparison of conventional and Fuzzy based smart city technique Signal to noise ratio(SNR) that cause interference in the cognitive radio sensing mechanism(dB)

Time (days)	Conventional Signal to noise ratio(SNR) that cause interference in the cognitive radio sensing mechanism(dB)	Fuzzy based smart city technique Signal to noise ratio(SNR) that cause interference in the cognitive radio sensing mechanism(dB)
1	8	10.32
2	8	10.32
3	8	10.32
4	8	10.32
10	8	10.32

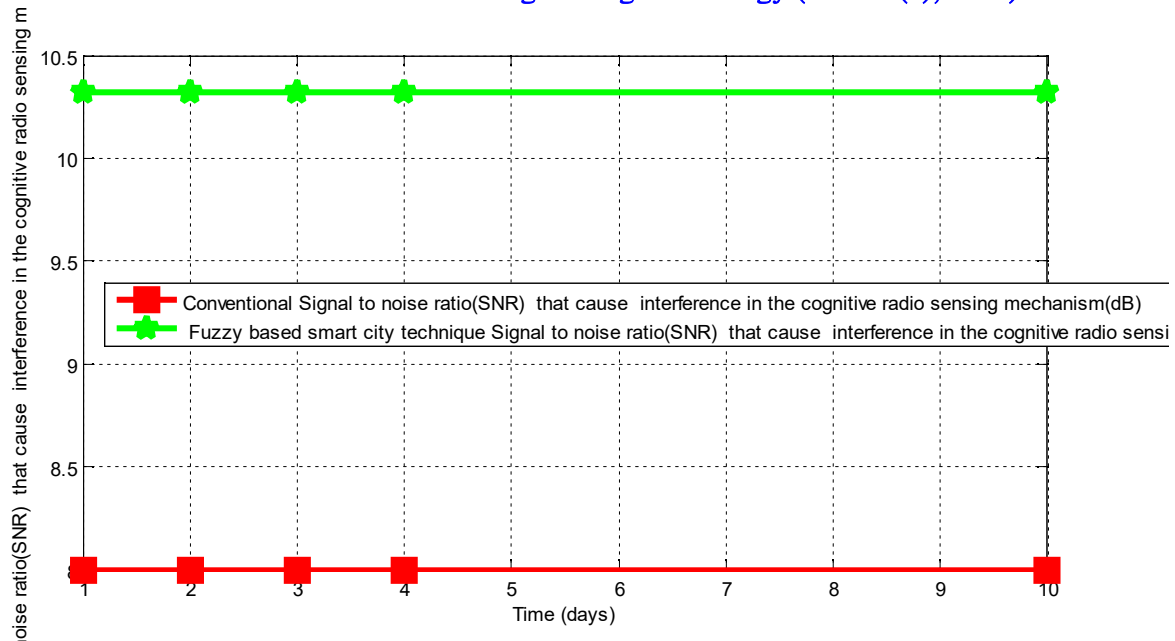


Fig 7: comparison of conventional and Fuzzy based smart city technique Signal to noise ratio(SNR) that cause interference in the cognitive radio sensing mechanism(dB)

The conventional Signal to noise ratio(SNR) that cause interference in the cognitive radio sensing mechanism was 8dB, On the other hand, when Fuzzy based smart city technique was incorporated into the system, it automatically increased to 10.32dB.

Table 3: comparison of conventional and Fuzzy based smart city technique interference to noise ratio INR that cause interference in the cognitive radio sensing mechanism(dB)

Time (days)	Conventional interference to noise ratio (INR that cause interference in the cognitive radio sensing mechanism(dB))	Fuzzy based smart city technique interference to noise ratio (INR that cause interference in the cognitive radio sensing mechanism(dB))
1	6	5.3
2	6	5.3
3	6	5.3
4	6	5.3
10	6	5.3

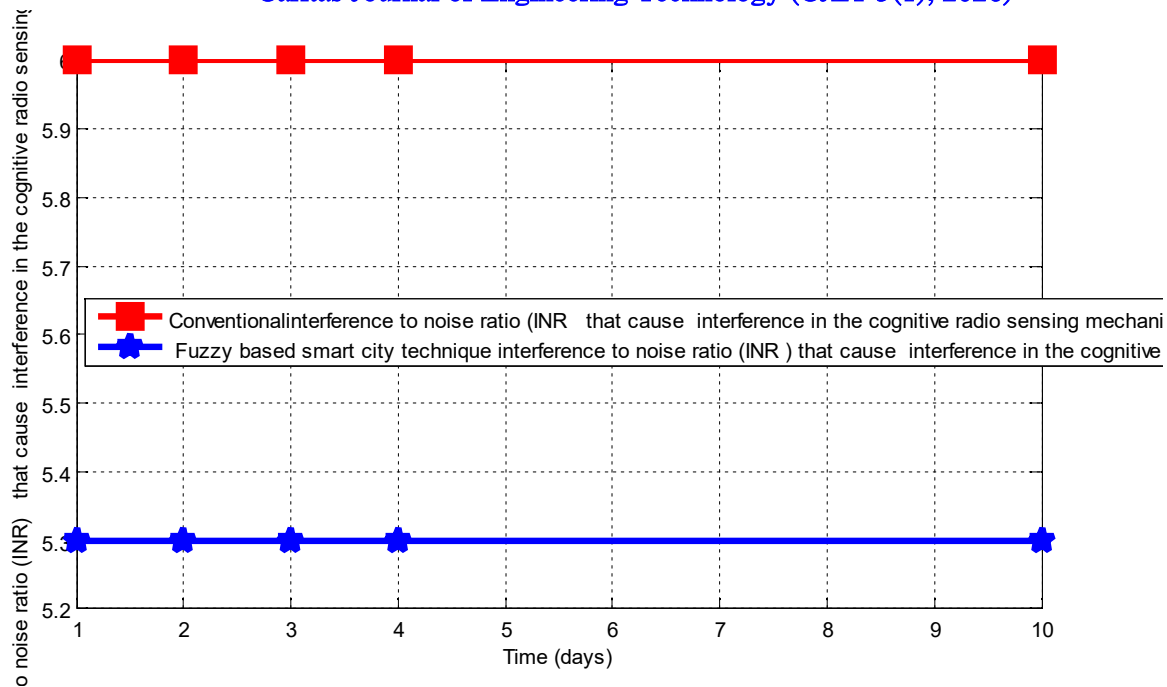


Fig 8: comparison of conventional and Fuzzy based smart city technique interference to noise ratio INR that cause interference in the cognitive radio sensing mechanism

The conventional interference to noise ratio INR that cause interference in the cognitive radio sensing mechanism was 6dB. Meanwhile, when Fuzzy based smart city technique was integrated into the system, it simultaneously reduced to 5.3dB. Finally, with these results obtained, it definitely meant that the percentage interference reduction in sensing mechanism of cognitive radio when Fuzzy based smart city technique was integrated into the system was 13.2%.

4.0 Conclusion

This study on Interference Reduction in Sensing Mechanism of Cognitive Radio Using Fuzzy-Based Smart City Technique has demonstrated the potential of intelligent decision-making frameworks in enhancing spectrum utilization and communication reliability in smart city environments. Cognitive radio networks, while offering dynamic spectrum access, often face the challenge of interference, which degrades sensing accuracy and leads to inefficient spectrum allocation. By integrating fuzzy logic with smart city infrastructure, the proposed approach effectively reduces uncertainties in spectrum sensing, optimizes decision thresholds, and improves detection probability under varying noise and channel conditions. The findings show that the fuzzy-based smart city technique enhances adaptability, minimizes false alarms, and significantly improves interference mitigation when compared with conventional sensing methods.

This advancement not only ensures seamless connectivity for diverse smart city applications—such as intelligent transportation, energy management, and public safety—but also strengthens the resilience of wireless communication systems in dense urban environments. In conclusion, the application of fuzzy-based intelligent techniques provides a robust and scalable solution for interference reduction in cognitive radio sensing mechanisms. Future research can extend this framework by integrating machine learning and blockchain-driven spectrum management to further enhance security, real-time adaptability, and autonomous decision-making within next-generation smart cities.

The conventional Signal to noise ratio(SNR) that cause interference in the cognitive radio sensing mechanism was 8dB, On the other hand, when Fuzzy based smart city technique was incorporated into the system, it automatically increased to 10.32dB and the conventional interference to noise ratio INR that cause interference in the cognitive radio sensing mechanism was 6dB. Meanwhile, when Fuzzy based smart city technique was integrated into the system, it simultaneously reduced to 5.3dB. Finally, with these results obtained, it definitely

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