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Bluetooth Performance in the Presence of Heterogeneous Communication System

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ABSTRACT:

The project aims to investigate the effect of heterogeneous noise in the environment on the transmission of Bluetooth and calculate the resulting data loss and transmission time at various distances. Bluetooth technology is widely used for wireless communication, but its performance can be affected by the presence of noise from other wireless technologies such as Zigbee and Wi-Fi. Understanding the impact of this noise is crucial for optimizing Bluetooth-based systems in noisy environments. The project involved conducting experiments to simulate heterogeneous noise by generating communication between Zigbee, Bluetooth, and Wi-Fi devices. Data loss in bytes and transmission time were measured and analysed at different distances between the transmitting ESP32 development kit and the receiving mobile Bluetooth device. The results demonstrated that as the level of heterogeneous noise increased, the data loss during Bluetooth transmission also increased, indicating a decrease in reliability. Additionally, the transmission time lengthened with increased distance, reflecting the attenuation of the signal strength. The experiment highlighted the significant impact of noise on Bluetooth transmission and the dependency of transmission performance on distance. The findings from this project have several practical applications. They can guide the design of wireless audio/video streaming systems, IoT devices, industrial automation systems, healthcare monitoring devices, and retail/hospitality applications, ensuring reliable communication in the presence of noise. The project also opens avenues for future modifications, such as advanced noise modelling, adaptive noise mitigation techniques, and integration with machine learning algorithms. Overall, this project provides valuable insights into the effects of heterogeneous noise on Bluetooth transmission. By understanding these effects and considering the design specifications, developers can optimize Bluetooth based systems for efficient and reliable communication in various real-world scenarios

Keywords: Bluetooth, noise, Wireless communication, Heterogeneous Communication

INTRODUCTION

Bluetooth technology has become indispensable in our daily lives, connecting a myriad of devices, from keyboards and speakers to printers and more. However, the simultaneous usage of diverse wireless devices, including Zigbee, Bluetooth, and Wi-Fi, has introduced concerns regarding data loss during Bluetooth transmissions. This project aims to investigate the impact of this heterogeneous noise on Bluetooth signals, focusing on data loss and transmission time. The study employs an ESP32 development kit as the Bluetooth transmitter and a mobile device as the receiver, introducing additional wireless devices to mimic real-world conditions. Bluetooth has evolved significantly, notably through the introduction of Bluetooth Low Energy (BLE) and subsequent versions, enhancing its range, data transfer capabilities, and application in various fields, including audio streaming and mesh networking. The project is motivated by the need to comprehend Bluetooth's performance within noisy environments, particularly to optimize its application in IoT and wireless audio systems. By examining the influence of heterogeneous noise on Bluetooth transmission, this project aims to contribute valuable insights for the enhancement of Bluetooth communication protocols. The primary objectives involve evaluating the impact of noise on transmission, quantifying data loss, measuring transmission time at varying distances, and analyzing the relationship between distance and Bluetooth performance. This comprehensive introduction provides an overview of the project's significance and sets the stage for the subsequent comprehensive literature review.

LITERATURE REVIEW

Performance Analysis of a Data Communication System Employing Bluetooth and Wi-Fi Standards simulated a half-duplex model using MATLAB to assess error performance, emphasizing the significance of HV1 voice packets and the impact of parameters on bit error rates. The study also discussed IEEE 802.11 WLAN and Bluetooth's operating frequencies, transmission rates, and spread spectrum techniques, along with the utilization of the OSI protocol stack and modulation techniques by Bluetooth. "Packet Error Rate Analysis of ZigBee Under WLAN and Bluetooth Inferences" focused on ZigBee's performance under WLAN and Bluetooth interferences, highlighting WLAN's dominant interference and providing coexistence criteria for ZigBee, WLAN, and Bluetooth. The exploration of "Bluetooth in Industrial Environment" scrutinized Bluetooth's throughput limitations, emphasizing

challenges in employing different packet types without forward error correction, suggesting the need for a more dynamic range of correction codes to enhance its applicability in diverse settings. These studies collectively contribute to understanding the capabilities, limitations, and coexistence of various wireless communication technologies in different environments.

METHODOLOGY

The experiment was conducted using an ESP32 development kit, with the following steps:

1. The Bluetooth and Wi-Fi modules were initialized, ensuring the proper functioning of the communication system.
2. The Zigbee module was configured to generate heterogeneous noise, simulating real-world environmental interferences during the experiment.
3. A stable Bluetooth connection was established between the ESP32 development kit and the mobile Bluetooth device, with the initial distance between the two devices meticulously set.
4. The timer was activated to precisely measure the duration of the transmission process, enabling the accurate assessment of the time required for data to be successfully transmitted between the source and the destination.
5. Video transmission was initiated from the ESP32 development kit to the mobile Bluetooth device, with continuous monitoring to detect any potential data loss or errors during the transmission process.
6. In the event of data loss or errors, the exact number of lost bytes was meticulously recorded, providing critical insights into the impact of heterogeneous noise on data integrity.
7. Upon successful completion of the transmission process without errors, the timer was stopped, and the transmission time was recorded for further analysis.
8. This comprehensive process was repeated for varying distances, incrementally increasing the distance between the ESP32 development kit and the mobile Bluetooth device, enabling a detailed examination of the relationship between distance and the quality of Bluetooth transmission under different environmental conditions.
9. The recorded data related to data loss and transmission time at each specific distance were diligently stored for subsequent analysis and visualization of the effect of heterogeneous noise on Bluetooth transmission.
10. To ensure the reliability and consistency of the results, the experiment was optionally repeated multiple times.
11. Finally, the experiment was concluded, and the findings were summarized, providing a comprehensive overview of the impact of heterogeneous noise on Bluetooth transmission and outlining the implications for the development of robust and efficient communication systems.

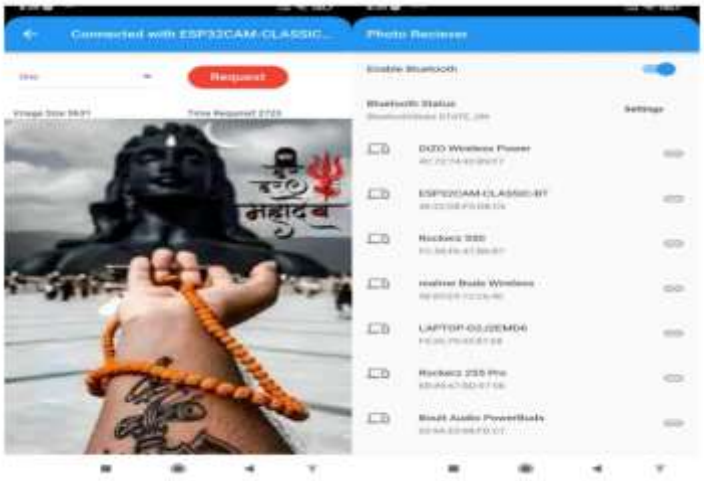

Fig 1. Bluetooth App

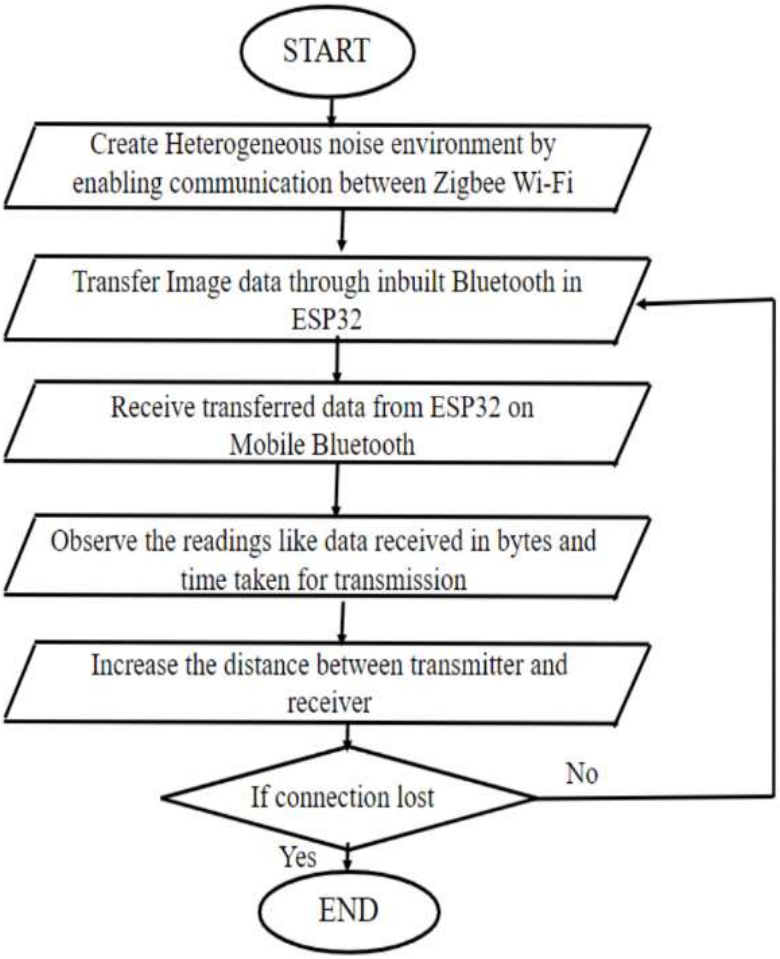

Fig 2. Flowchart

RESULTS

1. Data Loss: The experiment measured the amount of data lost during Bluetooth transmission under the influence of heterogeneous noise. The data loss was quantified in bytes, indicating the number of bytes that were not successfully transmitted. The results showed that as the level of heterogeneous noise increased, the data loss also increased. This suggests that the presence of noise in the environment negatively impacts the reliability of Bluetooth transmission.

2. Transmission Time: The experiment also measured the time required for Bluetooth transmission at various distances.The results indicated that as the distance between the transmitting device (ESP32 dev kit) and the receiving device (mobile Bluetooth) increased, the transmission time also increased. This is expected as the signal strength

weakens with distance, leading to longer transmission durations.

3. Impact of Heterogeneous Noise: The experiment observed that the presence of heterogeneous noise generated by the communication between Zigbee, Bluetooth, and Wi-Fi devices had a significant impact on Bluetooth transmission. The data loss increased and the transmission time lengthened in the presence of noise, indicating a decrease in the overall performance of Bluetooth communication.

4. Distance Dependency: The results highlighted the dependency of Bluetooth transmission on distance. As the distance between the devices increased, the transmission time increased, indicating a decrease in the efficiency of communication.

This suggests that Bluetooth is more suitable for short-range communication rather than long-range transmission.Overall, the experiment demonstrated that heterogeneous noise in the environment can adversely affect Bluetooth transmission. The results showed increased data loss and longer transmission times as the noise level and distance between devices increased.

These findings emphasize the importance of considering the impact of noise and distance when designing and implementing Bluetooth-based systems.

Distance (in Meters)	Transmission Time (in milliseconds)
1	2371
2	2623
3	2856
4	3278
5	3762
6	4227
7	4549
8	5036
9	6652
10	8654

Table 1. Result Table

Fig 3. Result Graph

Fig 4. Experiment Setup

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