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Intelligent Wireless Communication Using a Semantic-Aware Deep Learning Approach

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Abstract- The evolution of intelligent wireless systems requires moving from bit-level transmission to semantic communication. This work proposes a semantic-aware deep learning framework integrating NLP, semantic encoding, MQTT communication, and IoT actuation. Sentence-BERT generates 384-dimensional embeddings, compressed to a 32-dimensional latent space (12:1 ratio) using a lightweight autoencoder. Gaussian noise ($\sigma = 0.1, 0.2$) simulates realistic channel conditions. The model is compact (395 KB), with 98,688 parameters and 106,496 FLOPs, enabling efficient edge deployment. Results show high semantic preservation, with cosine similarity >0.95 for paraphrases and >0.90 under noise. Intent recognition achieves high confidence (0.9886 for "Light On" and 0.9782 for "Light Off"). Real-time validation using MQTT and ESP32 confirms reliable, low-latency control. The framework offers scalability, noise robustness, and spectral efficiency, making it suitable for 6G semantic communication systems.

Keywords: Semantic Communication, Deep Learning, Semantic Autoencoder, Sentence-BERT, MQTT, ESP32, IoT Control, 6G Wireless Systems.

I. INTRODUCTION

The next generation of intelligent networks may use semantic communication that incorporates IoT technologies. Semantic-aware systems and the shifting trend of wireless communication to 6G are expected to significantly reduce communication overhead, increase efficiency, and provide the ability to communicate with devices in future settings. The solution developed for this project demonstrates a workable implementation of this idea within the scope of fusing real control over IoT devices with semantic processing based on deep learning.

In general, the proposed semantic framework of communication shows how meaning-oriented communication can be applied to enhance the effectiveness and intelligence of wireless systems. By sending useful information rather than raw data, the system provides a more effective, flexible, and intelligent means of communication, paving the way for future advancements in AI-based wireless networks and smart surroundings.

II. OBJECTIVE OF RESEARCH

To create and establish a semantic-aware AI-based wireless communication system, which transmits and re-creates meaningful information in an efficient manner using deep learning and embedded hardware.

Objectives

1. To establish a semantic encoder and decoder of text communication with the help of deep learning.
2. To adopt semantic data transfer among hardware nodes.
3. Simulation of wireless channel effect and robustness.

4. To compare semantic communication with the traditional bit-based transmission.

III. METODOLOGY

Figure 3.1 presents the general working process of the suggested semantic communication system that should be used in the control of smart home devices. The architecture illustrates the way in which natural language instructions that were issued by the user are fed through semantic communication elements and eventually converted to actual physical device action.

This starts at PC-1 (Semantic Sender), which requires the user to type a natural language command into the graphical interface. This command can consist of commanding something like turning a light on or turning a fan on. The command is sent by the sender application to the subsequent processing.

PC-2 (Semantic Receiver) then takes the command and makes semantic analysis with deep learning models like Sentence-BERT. Semantic similarity and intent recognition processes help the receiver system to decode the meaning of the command and identify the action to be performed by a device.

Once the receiver has specified the appropriate intent of the device, it sends a control message with the MQTT communication protocol to an MQTT broker. The broker is a communication server that facilitates communication between the devices in an efficient manner through a publish subscribe architecture.

The microcontroller that is the actuator device in the system is called ESP32, and it subscribes to the corresponding MQTT topics. When a control command is sent to the ESP32, a message is processed and the relay module associated with the physical device is turned on.

Lastly, the relay module is used to alternate the electrical circuit and hence, the physical gadgets, e.g., a light bulb or a fan. This makes the user input to device actuation semantic communication pipeline complete.

Altogether, the figure illustrates the combination of natural language processing, semantic communication model, MQTT-based IoT communication, and embedded hardware control that allow building an intelligent and efficient smart home automation system. The architecture emphasizes the semantic interpretation of commands to enable flexible interpretation of command and reliable real-time interpretation of devices.

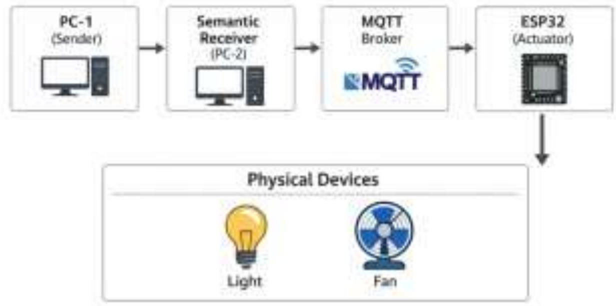

Figure 1: Overall System Workflow of the Semantic Communication Based Smart Home Control System

IV. RESULT

Figure 5.2: ESP32 Controller with OLED Display for System Status Monitoring

The ESP32 microcontroller with an OLED display module shown in Figure 5.2 is utilized to monitor the state of the system. The OLED screen provides the real-time status of devices which are connected like Light, Fan, AC and TV together with network connection status.

The display also shows the success of connectivity either to Wi-Fi or MQTT.

The given feedback mechanism enables the user to visually check the state of the semantic communication mechanism and make sure that commands are being performed properly.

Figure 5.3: Semantic Sender Interface for Command Transmission

The graphical user interface of the Semantic Sender application that was written to help in the transmission of natural language commands is shown in Figure 5.3. The sender interface enables the user to key in the commands or to use some quick command buttons like the Light ON, Fan OFF or AC ON. After a command has been typed in, the Sentence-BERT model is used to convert it into a semantic embedding that is sent via the MQTT protocol. There is also a command history that is captured by the interface whereby the user can monitor historical commands that have been sent.

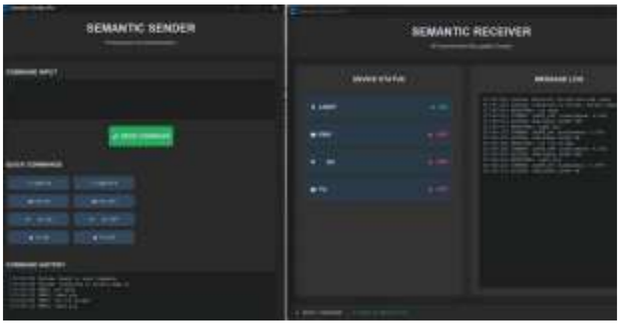

Figure 5.4: Semantic Receiver Interface with Device Status Monitoring

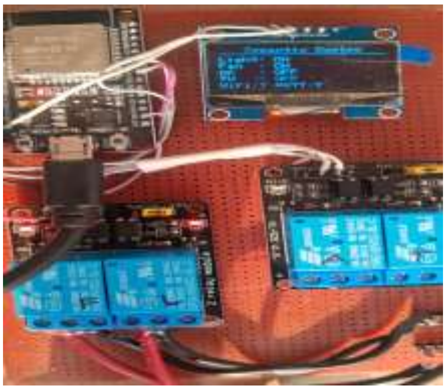

Figure 5.6: Execution of Light Control Command

Figure 5.6 shows how a semantic command to control the light device has been successfully executed. Upon getting the command, the receiver system decodes the intent and post the corresponding MQTT message. The ESP32 controller gets the command and turns on the relay module in question. The OLED display will verify the device condition by reporting that the light is turned ON.

Figure 5.7: Execution of Fan Control Command

The working of the system when a semantic command is given to manage the fan device is illustrated in figure 5.7. The receiver application takes the fan control intent and publishes the command using the MQTT broker. The relay to the fan is then triggered by the ESP32 module. OLED display and relay indicator lights ensure that the fan has been activated.

V. CONCLUSION

By focusing on the semantics of orders rather than the precise textual input, the proposed semantic communication model as a whole improves human-smart environment interface engagement. This would enhance the intelligent home automation systems' robustness, communication efficiency, and usability. The study demonstrates the viability of implementing AI-powered semantic communication with IoT-based smart device control.

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