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WirelessLLM: Empowering Large Language Models Towards Wireless Intelligence

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Background

- 6G networks necessitate a paradigm shift in how communication systems are designed, configured, and managed.
- Large language models (LLMs) have potentials to revolutionize wireless communication systems.

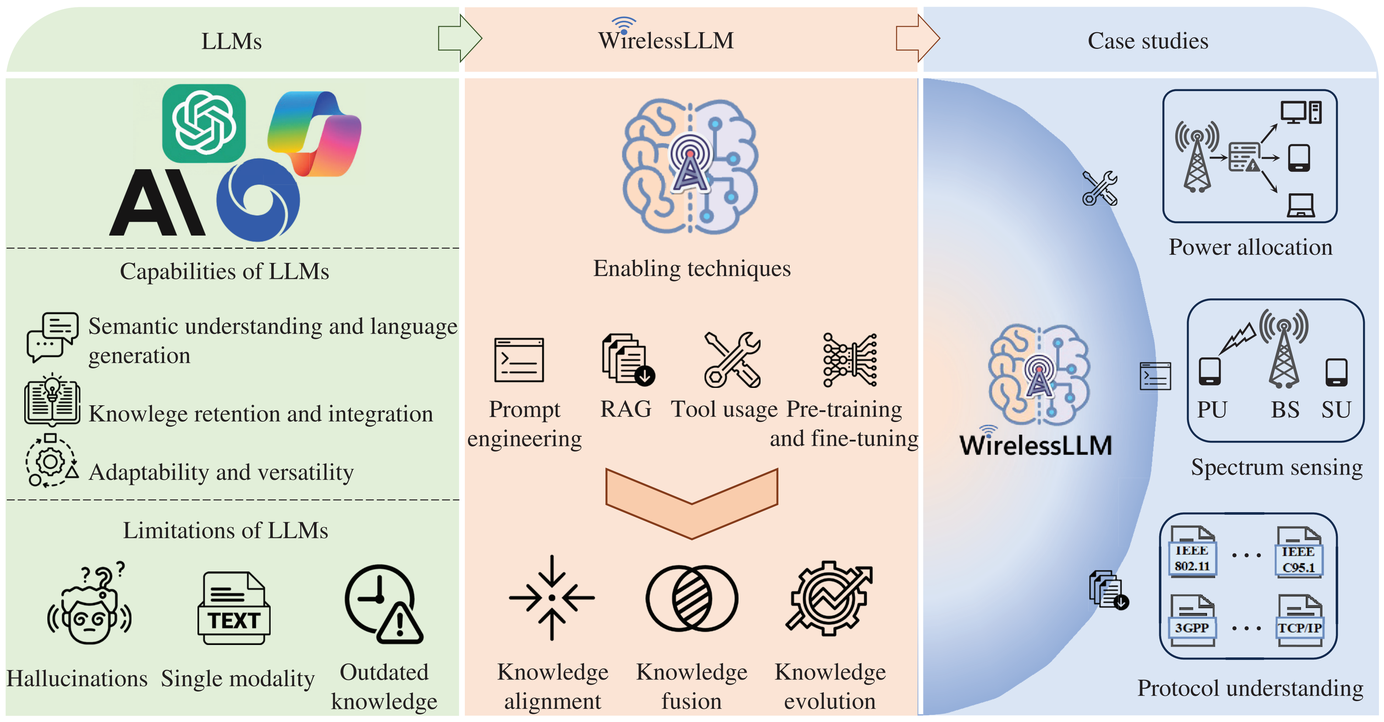
Motivation

- Existing studies on LLMs for wireless systems are limited to direct applications in telecom language understanding.

Contributions

- We identify three foundational principles that underpin WirelessLLM: knowledge alignment, knowledge fusion, and knowledge evolution.
- We investigate the enabling technologies to build WirelessLLM: prompt engineering, RAG, tool usage, pre-training, and fine-tuning.

WirelessLLM Overview



WirelessLLM for Power Control

Naive use of ChatGPT

Input

Q: Consider a power allocation problem in OFDM system. [Same system configuration]. What is the optimal power allocation to maximize the overall capacity?

Output

A: In the scenario you've described for an OFDM system with power allocation across multiple subcarriers, the optimal power allocation method to maximize the overall system capacity under given channel conditions is typically done using water-filling algorithm, which assigns more power to subcarriers with higher channel-to-noise ratios (CNR).

Based on this strategy:

- Subcarriers with higher channel gains like 12.8049, 7.6698, and 5.1024 would get a significantly higher proportion of the power.
- Subcarriers with moderate gains like 3.3631 and 1.7100 would receive moderate amounts of power.
- Subcarriers with low channel gains like 0.2891, 0.1016, 0.1880, 0.1174, and 0.7433 might receive very little or no power allocation, focusing the power where it can most effectively be utilized to maximize the data rates.

✗ Fail to obtain results

WirelessLLM Framework

Input

Q: Consider a power allocation problem in OFDM system. There are 10 subcarriers. The total transmit power budget is 1. The channel gain of each subcarrier is [0.2891, 3.3631, 5.1024, 0.7433, 0.1016, 1.7100, 0.1880, 0.1174, 12.8049, 7.6698]. The noise power is 0.1. What is the optimal power allocation to maximize the overall capacity? Think step by step, with runnable Matlab code associated with each step.

Output

A: Step 1: Calculate CNR for each subcarrier:

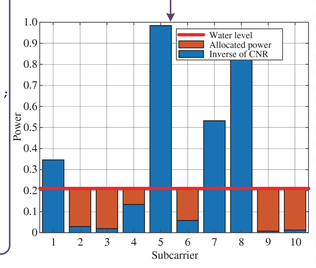
```
channel_gains = [0.2891, 3.3631,
….,7.6698];
noise_power = 0.1; cnr = channel_gains/
noise_power;
```

Step 2: Water-filling algorithm with bisection Search:

```
total_power = 1; mu_min =0; mu_max =
max(1./cnr);
epsilon = 1e-5;
while mu_max - mu_min > epsilon
   mu = (mu_min + mu_max)/2;
   power allocation = max (0, mu - 1./cnr);
   total_allocated_power =
sum(power_allocation);
   if total_allocated_power > total_power
        mu_max = mu;
   else
        mu_min = mu;
   end
end
power_allocation = max(0, mu - 1./cnr);
```

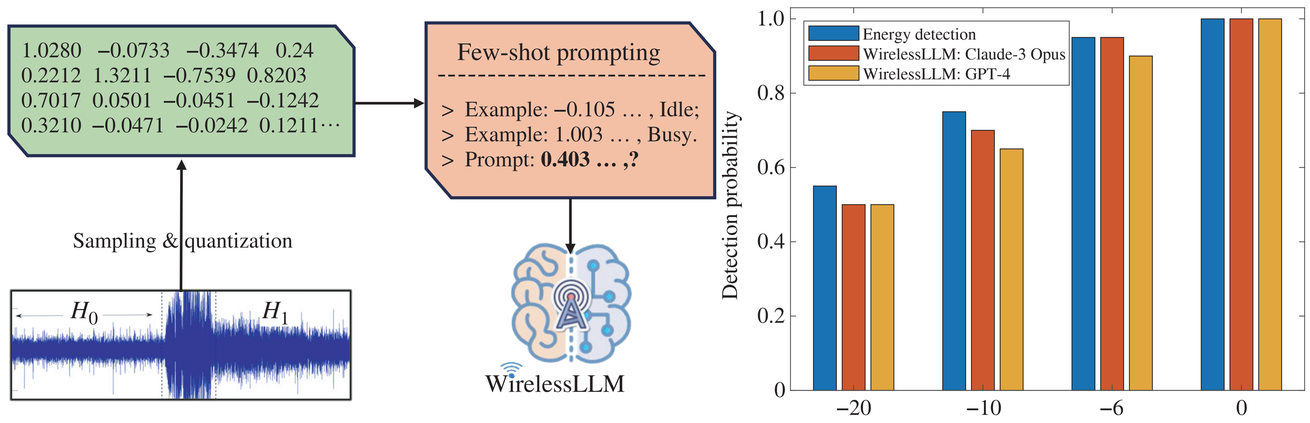
External toolkits: python, MATLAB

Final results



✓ Correct water-filling solution

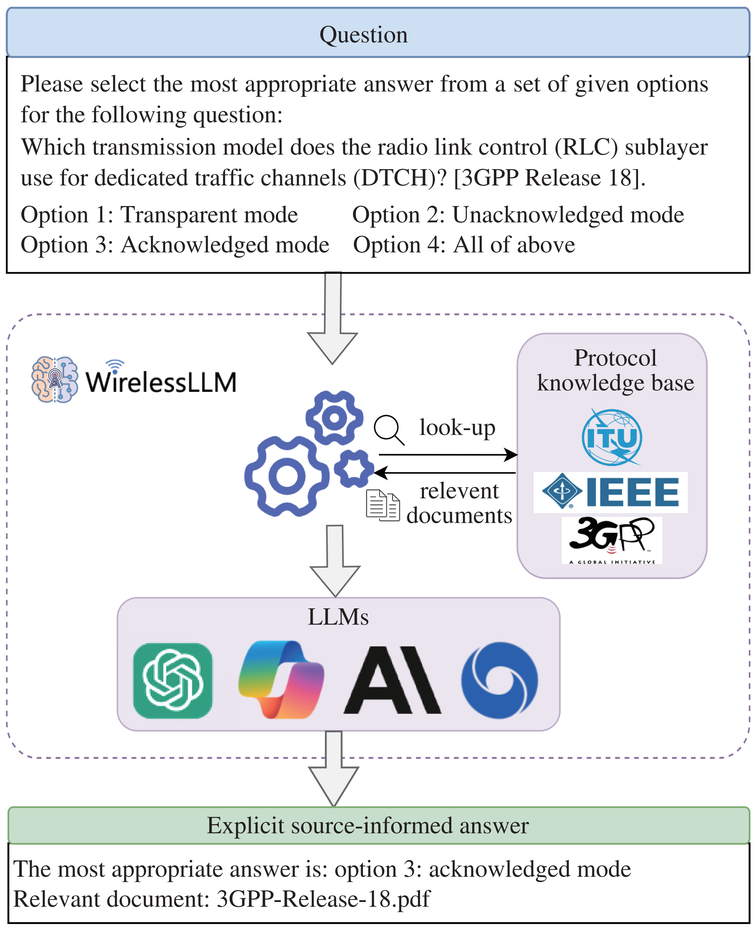
WirelessLLM for Spectrum Sensing



WirelessLLM framework with few-shot prompt

Numerical results

WirelessLLM for Protocol Understanding



Performance Comparison

Category	GPT-3.5	GPT-4	WirelessLLM
Lexicon	84.08%	89.42%	89.61%
Research overview	70.45%	73.08%	73.55%
Research publications	72.38%	79.30%	79.78%
Standards overview	66.12%	76.54%	86.54%
Standards specifications	59.05%	66.89%	80.34%

Links

Full paper

Video

WeChat

Acknowledgment

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