# Shells on Constrained Devices

## Using CoAP to explore new UX paradigms for embedded shells

**Bennet Blischke 11.07.2024**

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  - Command Line Interface (CLI)
  - Graphical User Interface (GUI)

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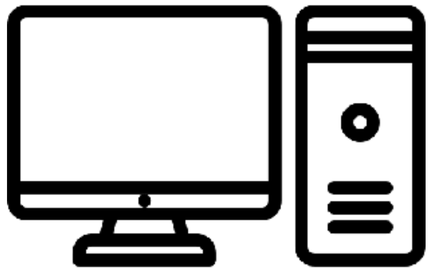

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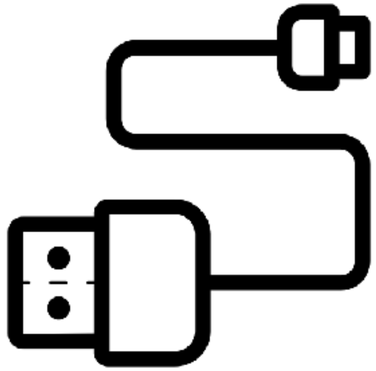

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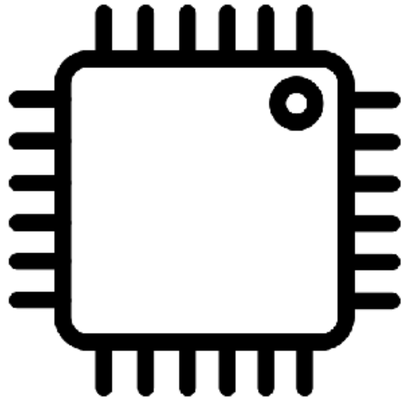

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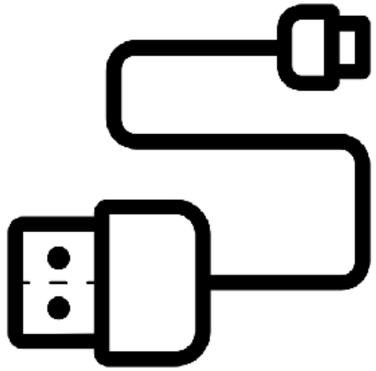

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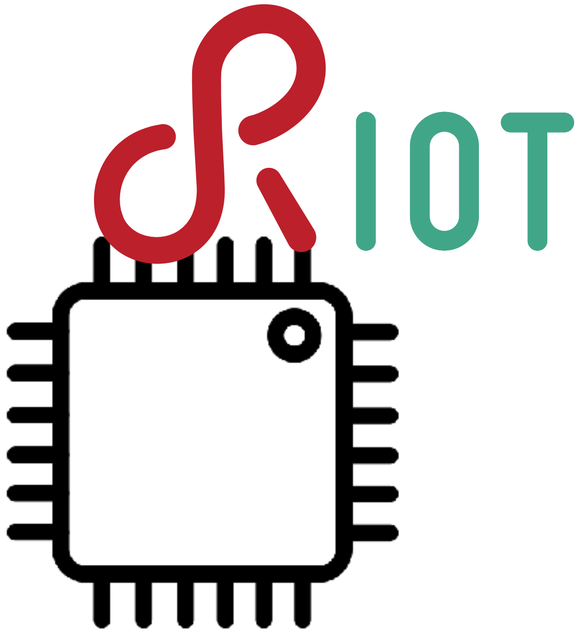


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> reboot
2024-07-09 11:05:35,533 # reboot
2024-07-09 11:05:35,542 # main(): This is RIOT! (Version: 2024.07-devel-135-g46924-feat/slipconf)
2024-07-09 11:05:35,543 # Welcome to RIOT!
>
```

# Shortcomings

- ROM / RAM overhead due to string-parsing on the constrained device
- It’s complicated to exchange binary data via an ASCII stream
- No correlation between received text and origin
    - First thread starts to write
    - Another thread interrupts & writes its own message
    - First thread continues and finishes its message
    - The re out of order sult is hard to read and

# Shortcomings

- Long running and highly asynchronous tasks block the shell
- Difficulties in unit-/automated testing of shell components
- Signalling of success and failure of commands

# The Issue with String Parsing

## ROM / RAM overhead due to string parsing on the constrained device

- Strings require a lot of ROM, one byte per character
  - TOP That just was 53 bytes!
- Even worse, when formatting strings. Example:
  - printf(“Year %d”, year);
  - 7 bytes for the format string
  - 9 bytes for the result “Year 2024”

# The Issue with String Parsing

## ROM / RAM overhead due to string parsing on the constrained device

- We do a lot with strings in our shells
- A command takes strings as parameter: ifconfig(int argc, char *argv[])
- Now, parse “ifconfig 7 set channel 0x21”
- A command outputs its result by printing formatted strings
    - Try printing a table of running threads

# How do We Improve?

## Format Strings

- Deferred Formatting:
  1. Assign all format strings a short ID
  2. Only compile the ID into the firmware
  3. When printing, send the ID + format values as it
  4. On the host, look up corresponding strings for received IDs
  5. Format and print on the host side

For an example see:

https://defmt.ferrous-systems.com/

# How do We Improve?

## Correlating output to commands

- We need a lightweight **A**pplication **P**rotocol
- Suitable for **Co**nstrained devices
- Allows to issue a command with optional parameters
- Provides request & response matching
- Can handle errors:
    - On the host side e.g. “invalid parameter for command”
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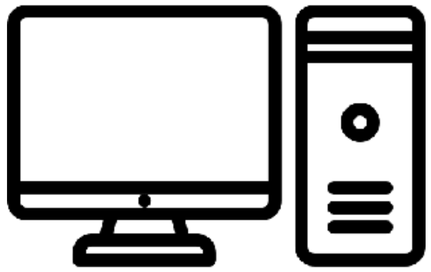
That’s CoAP!

# Even More CoAP Benefits!

- Completely asynchron: Request now, get the response later!
- With CoAP Observe, we can have timer, events and interrupts in our shell
- Big binary payload? CoAP block-wise transfer saves the day
- Robust ecosystem due to related standards:
    - Discover shell commands via /.well-known/core
    - Describe commands using CoRE Link Format

# CoAP transports via UDP…

## … but we don’t have UDP, not even IPv6!



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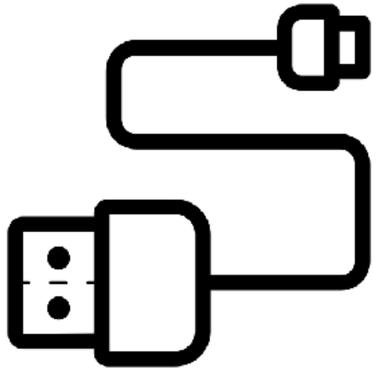

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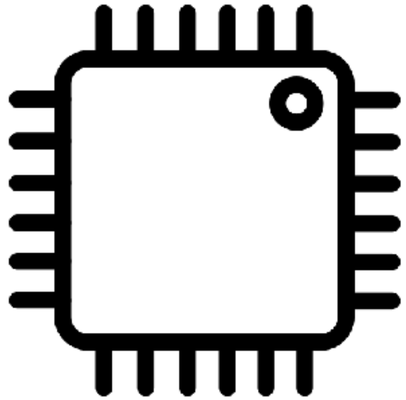

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Can we speak CoAP over UDP over IP via SLIP?

Yes!

But that’s a lot of overhead, we just want CoAP

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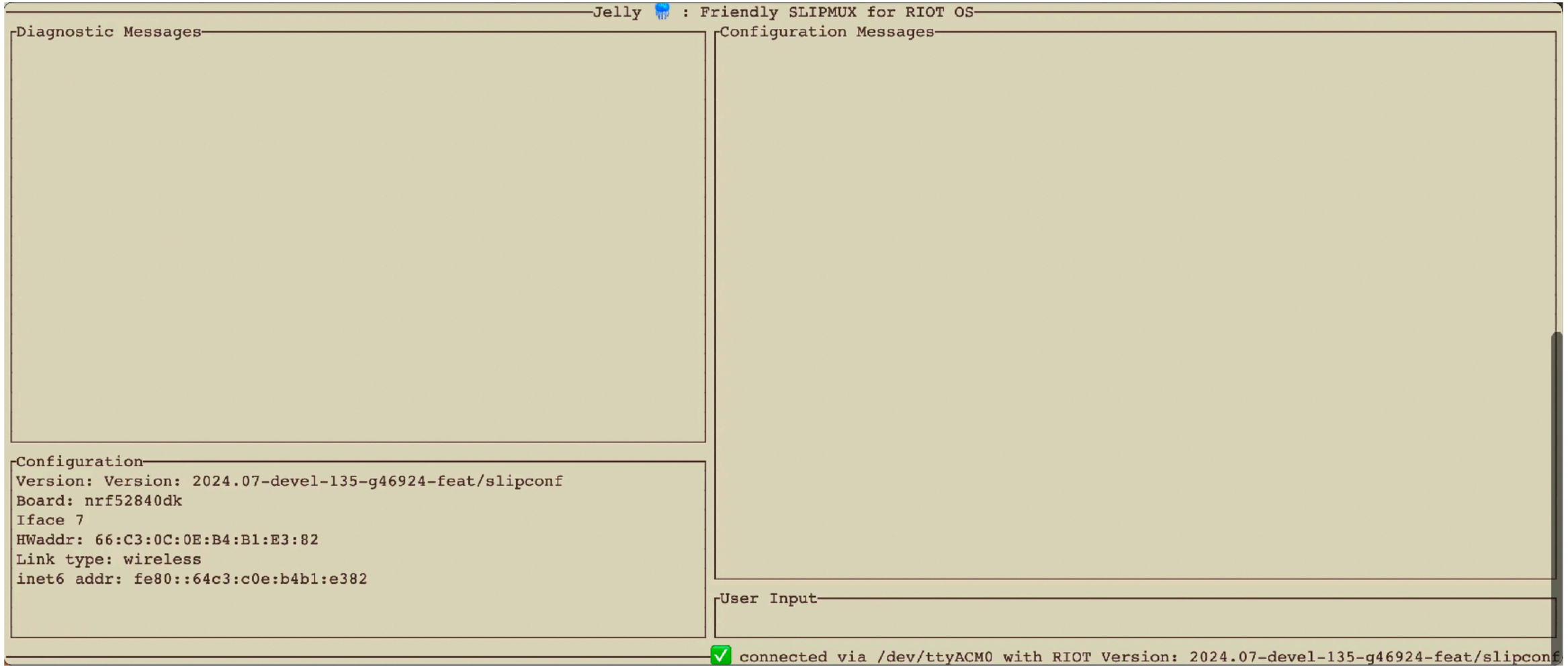
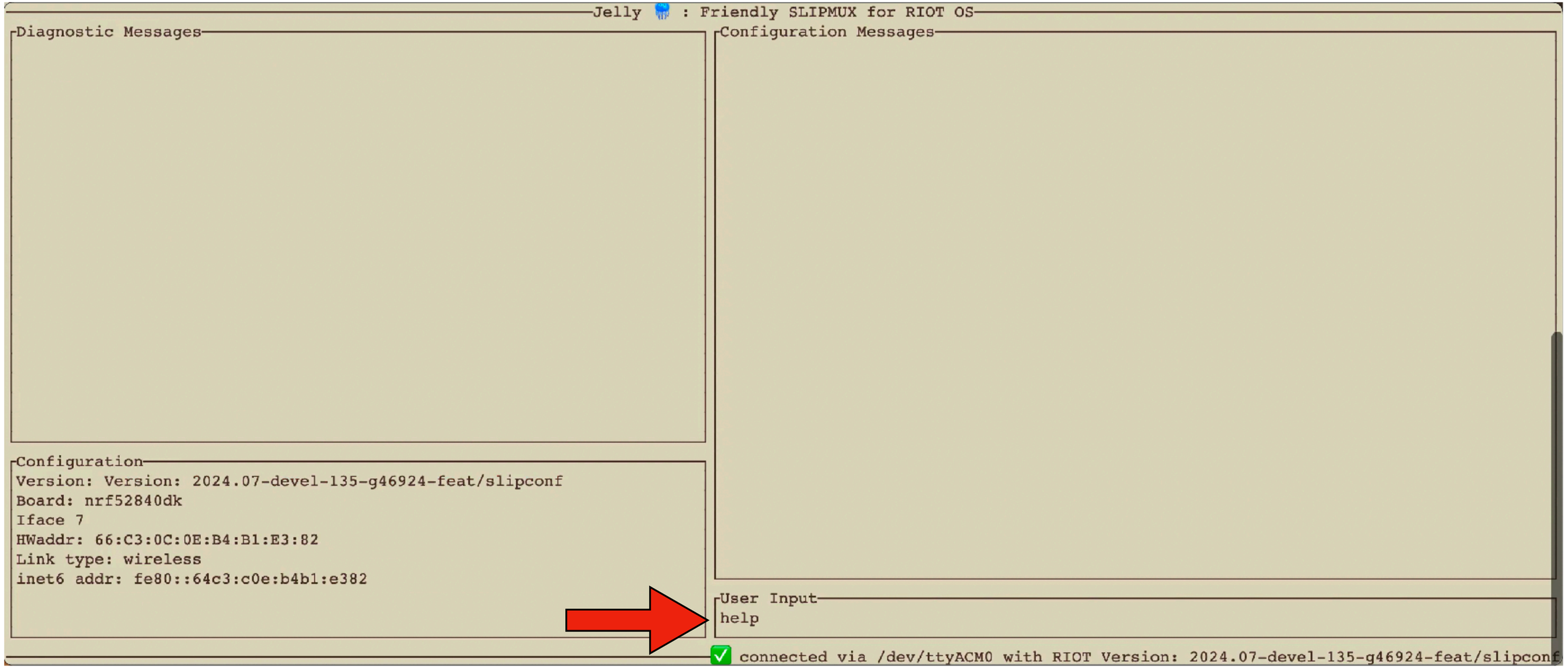
- **Configuration** messages are **CoAP packages**!
  - This also solves the issue of finding the IP addresses of both participants
- And if we want, we can still exchange IP frames

# Let’s prototype!

## What does a SLIPMUX client look like?



# Backwards compatible: help



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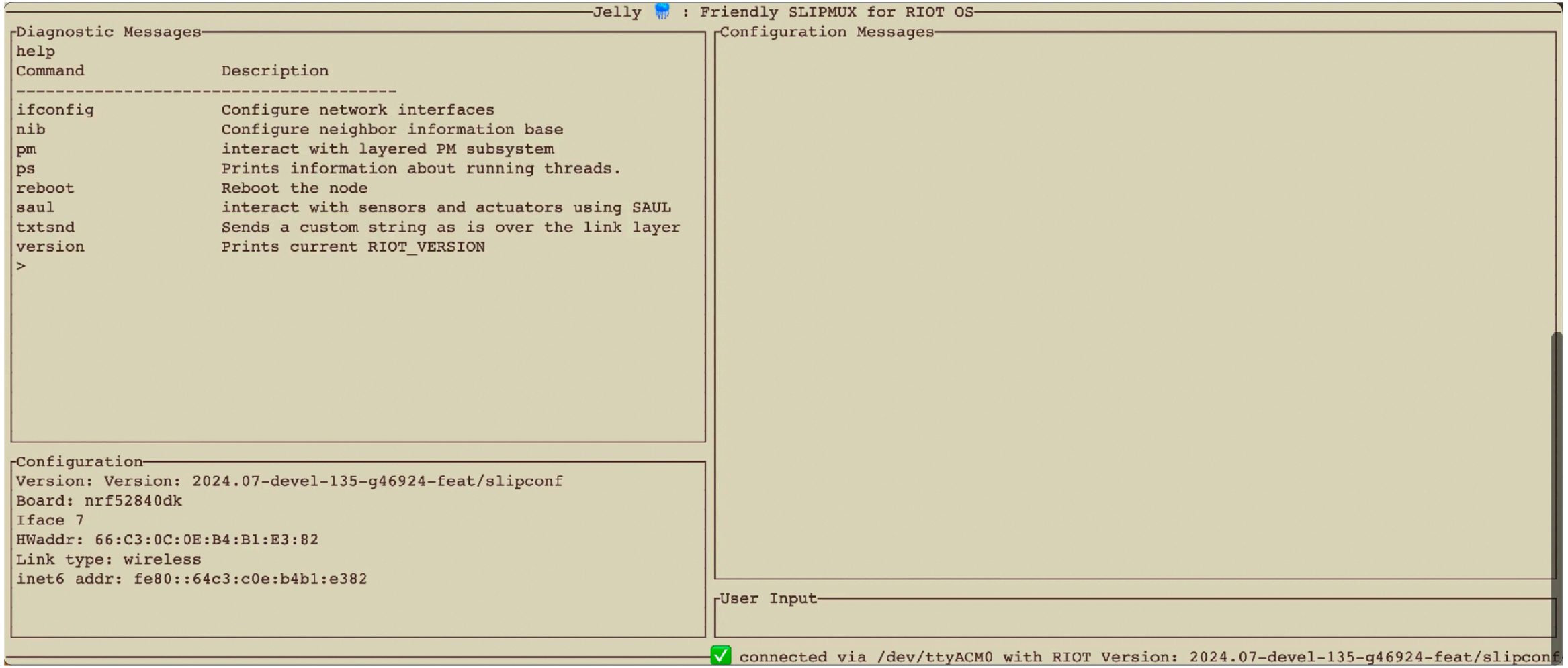
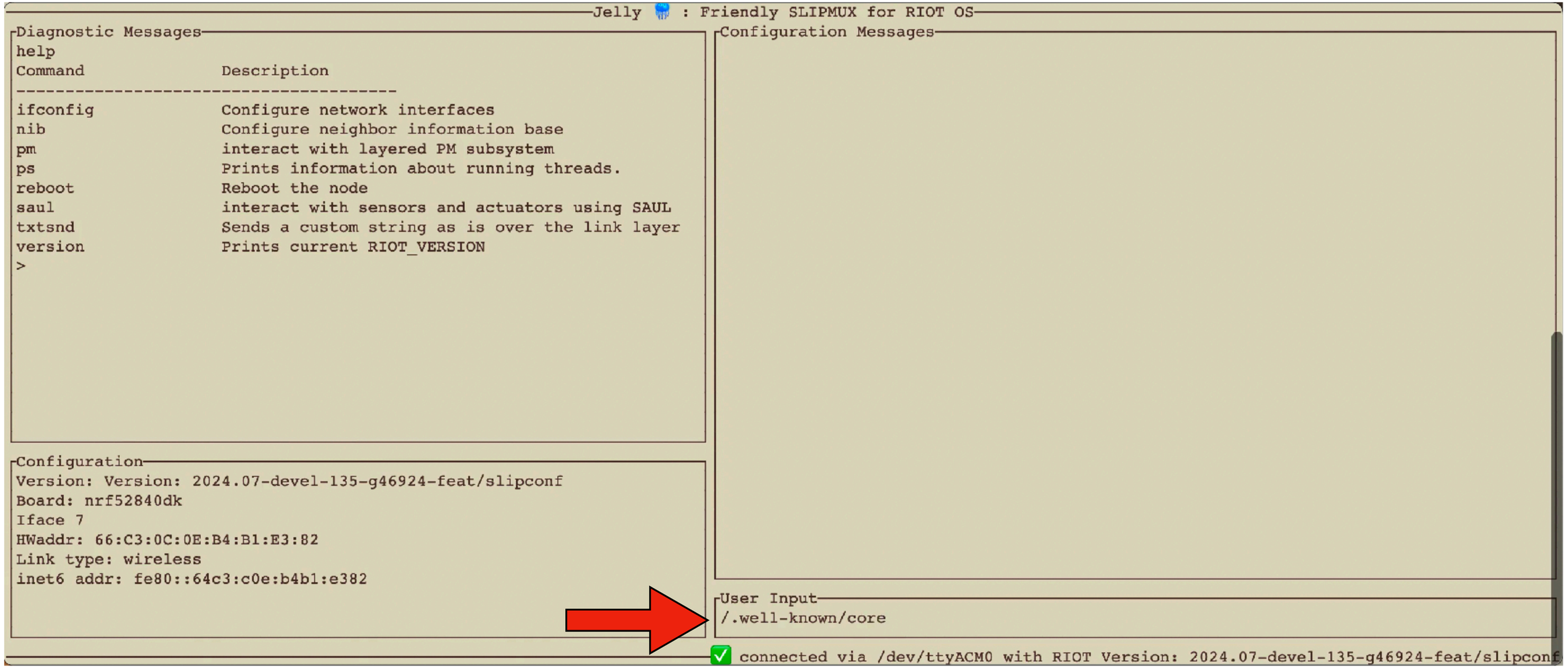


# New: Direct CoAP Requests

## GET /.well-known/core



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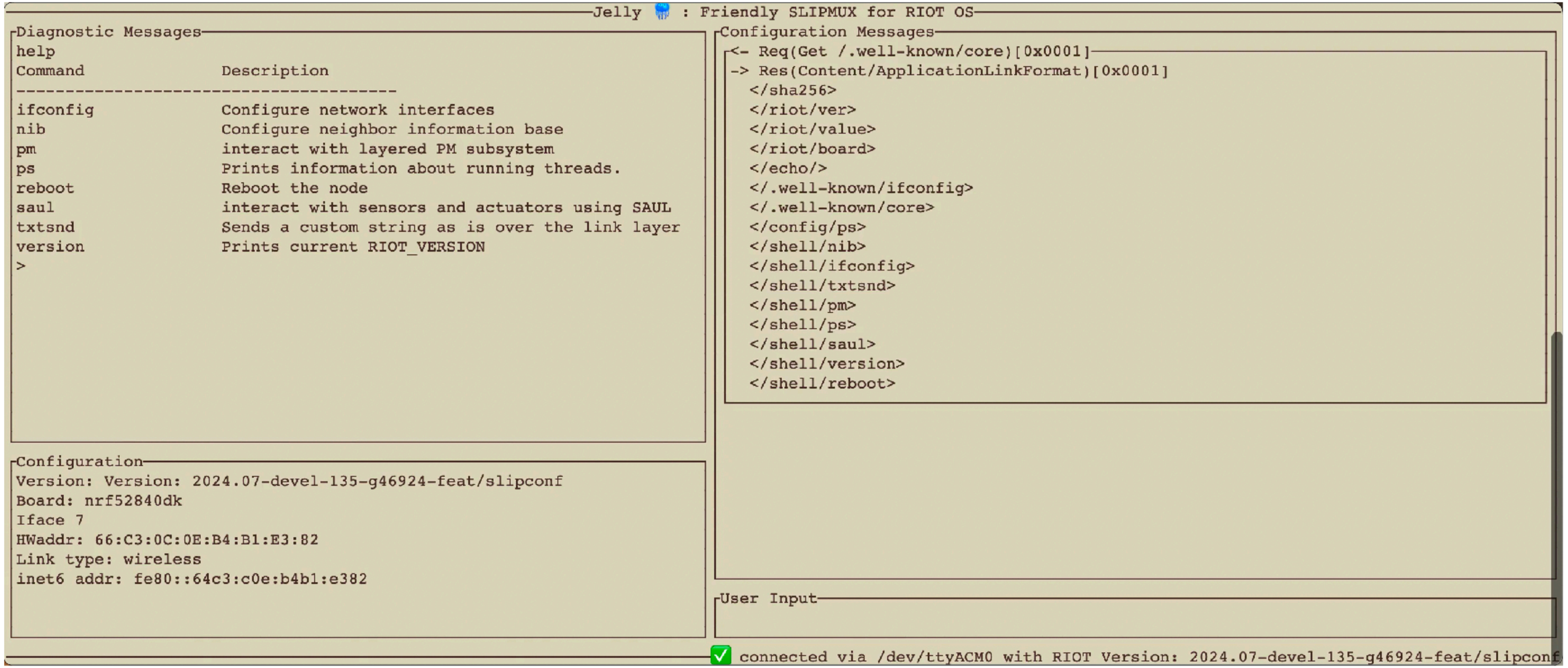
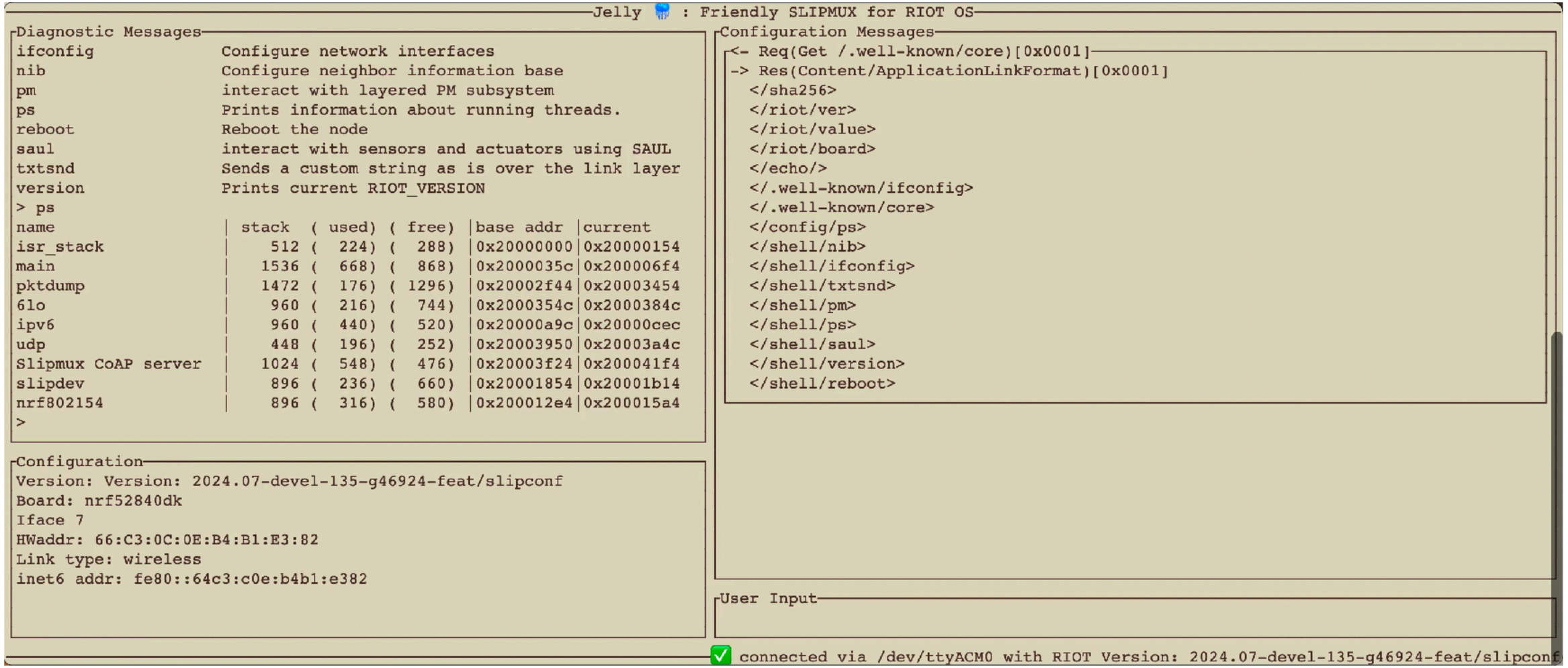
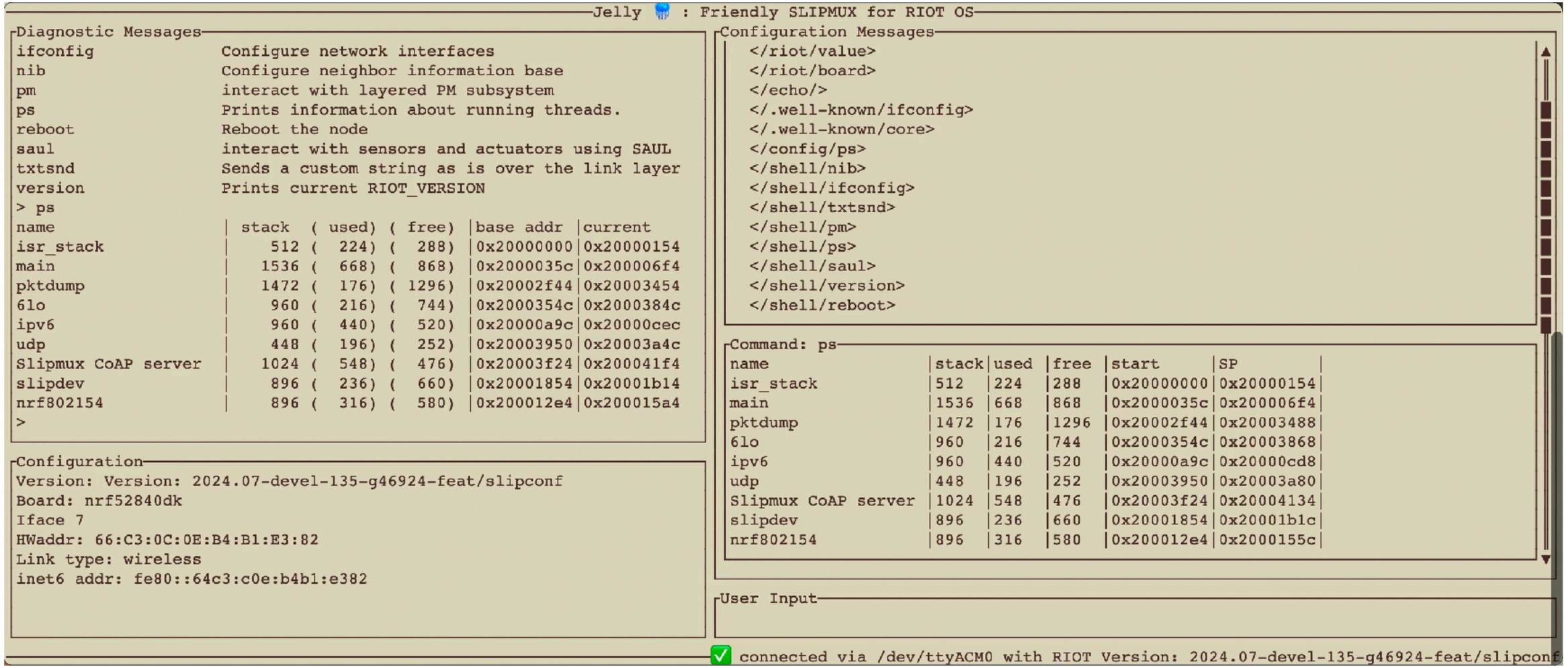


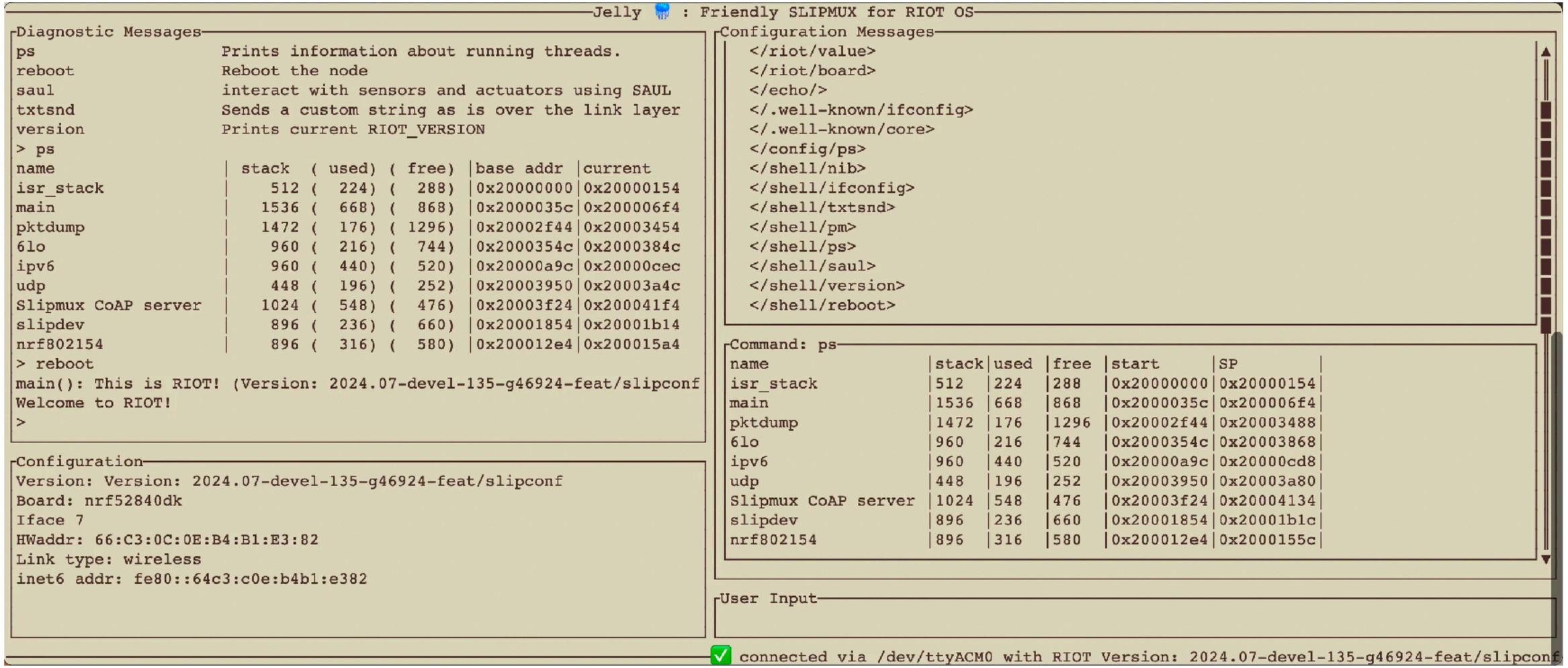
# Backwards Compatible: ps



# Commands via CoAP: ps



# Backwards Compatible: reboot



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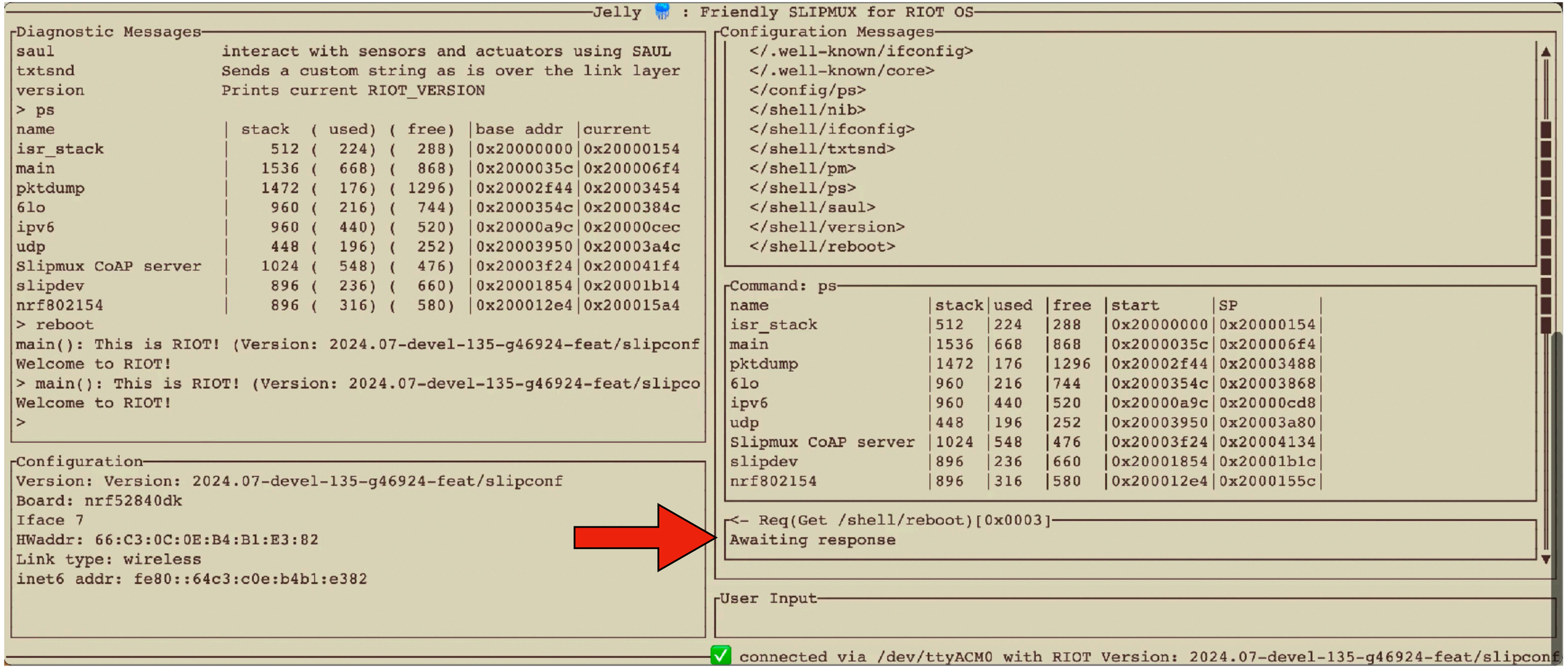


# That was more than just a Shell!

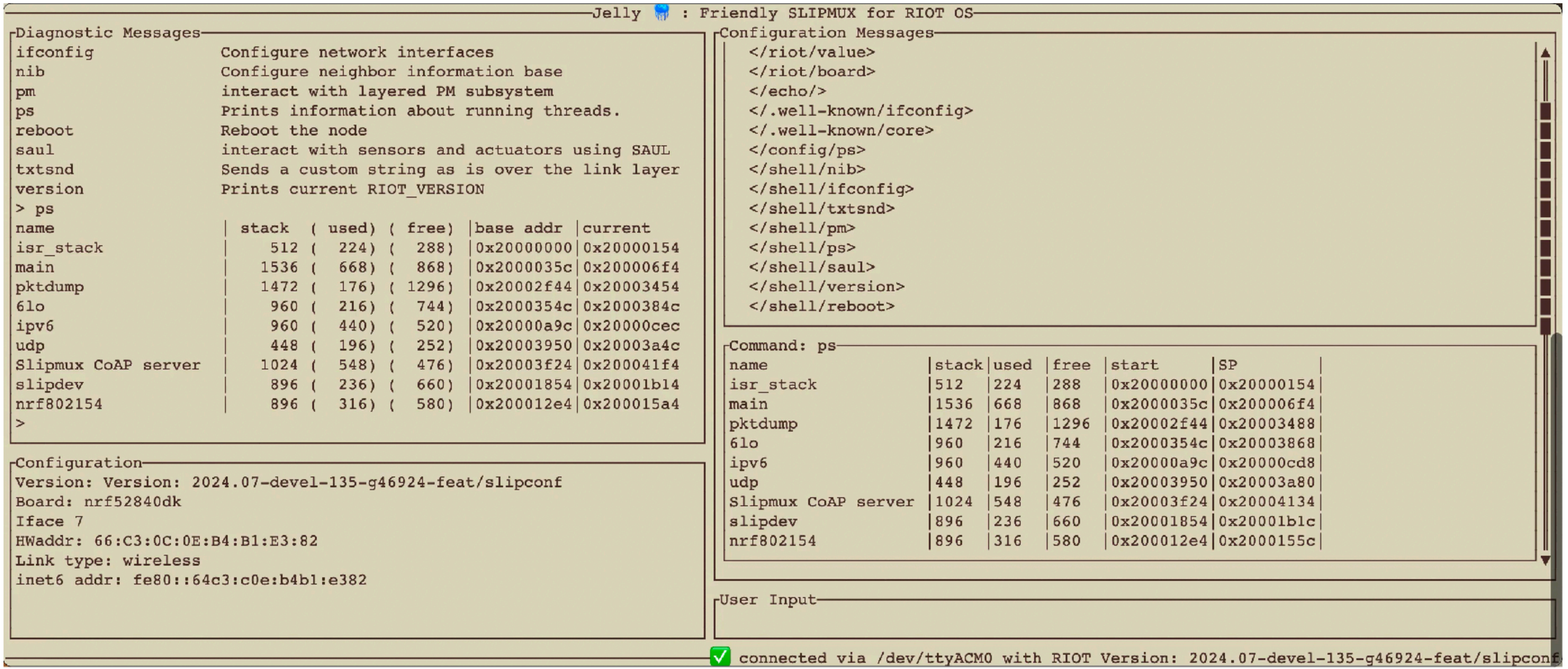
- Because CoAP is not build for human consumption but for machines, we can do cool things now:
    - Auto detect and auto complete available shell commands
    - Automagically fetch and display useful debugging informations such as version and IP addresses of the constrained device
    - Digest binary payloads: present them human readable, save to disk, ..
    - Chain multiple shell commands, passing their I/O into each other

# Conclusion & Outlook

- It is feasible to use CoAP as a basis for a modern shell
- Greatly improved usability
- But there is so much more todo!
    - Structured parameter and return values of commands, e.g. CBOR
    - Interoperability between “new” and “old” shell
    - Security aspects: Opening the shell to the network
    - ROM increase due to CoAP vs. decrease due to reduced string parsing

# Bonus Slide: Early Overhead Estimations

## Comparing the old `ps` vs. the new CoAP `ps`



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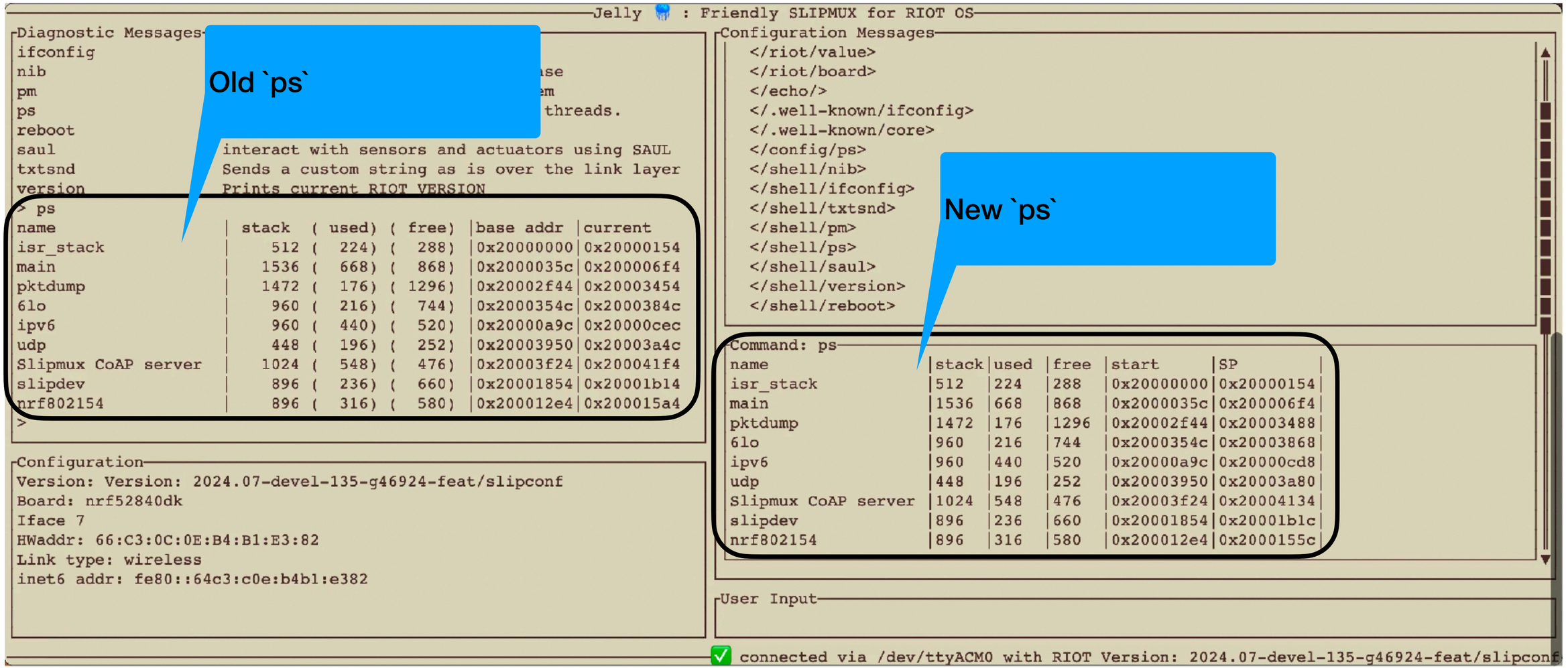

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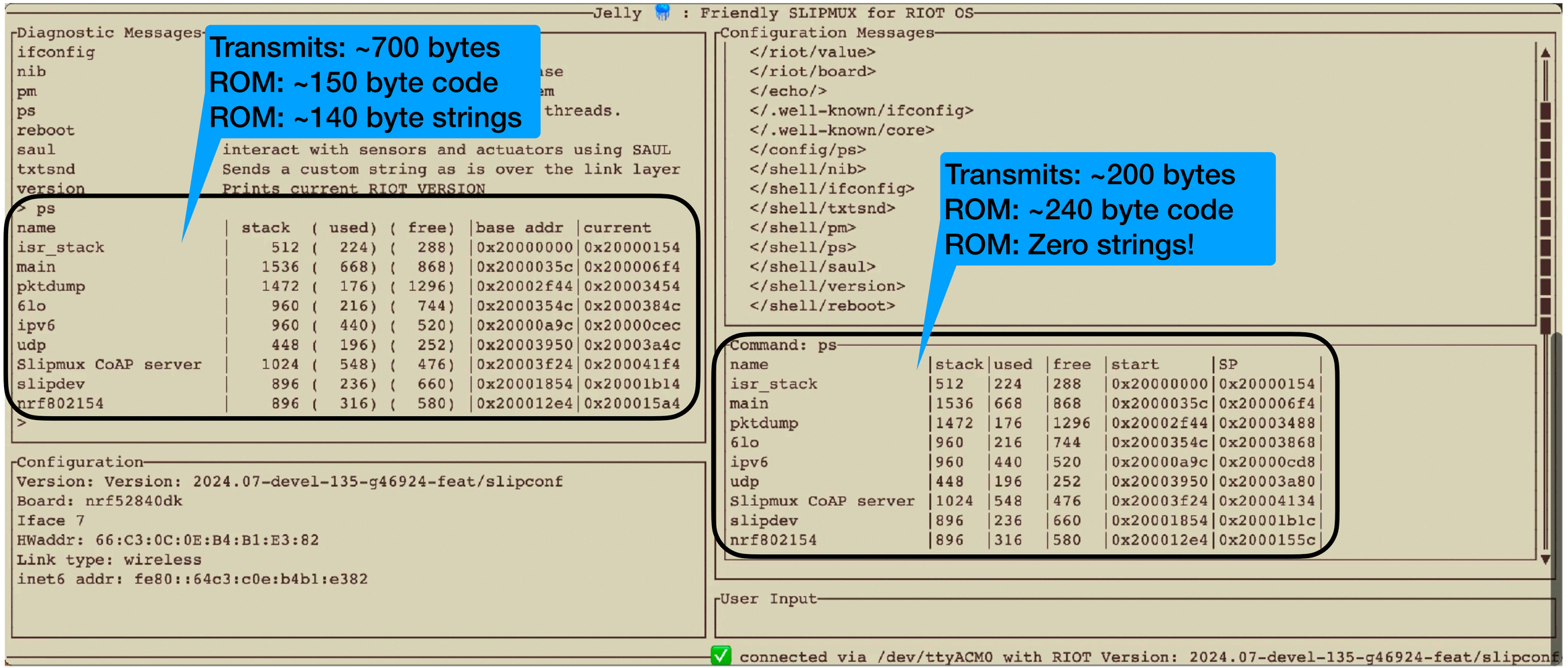

# Thank you for having me!