Intro to Networking

Ryan Eberhardt

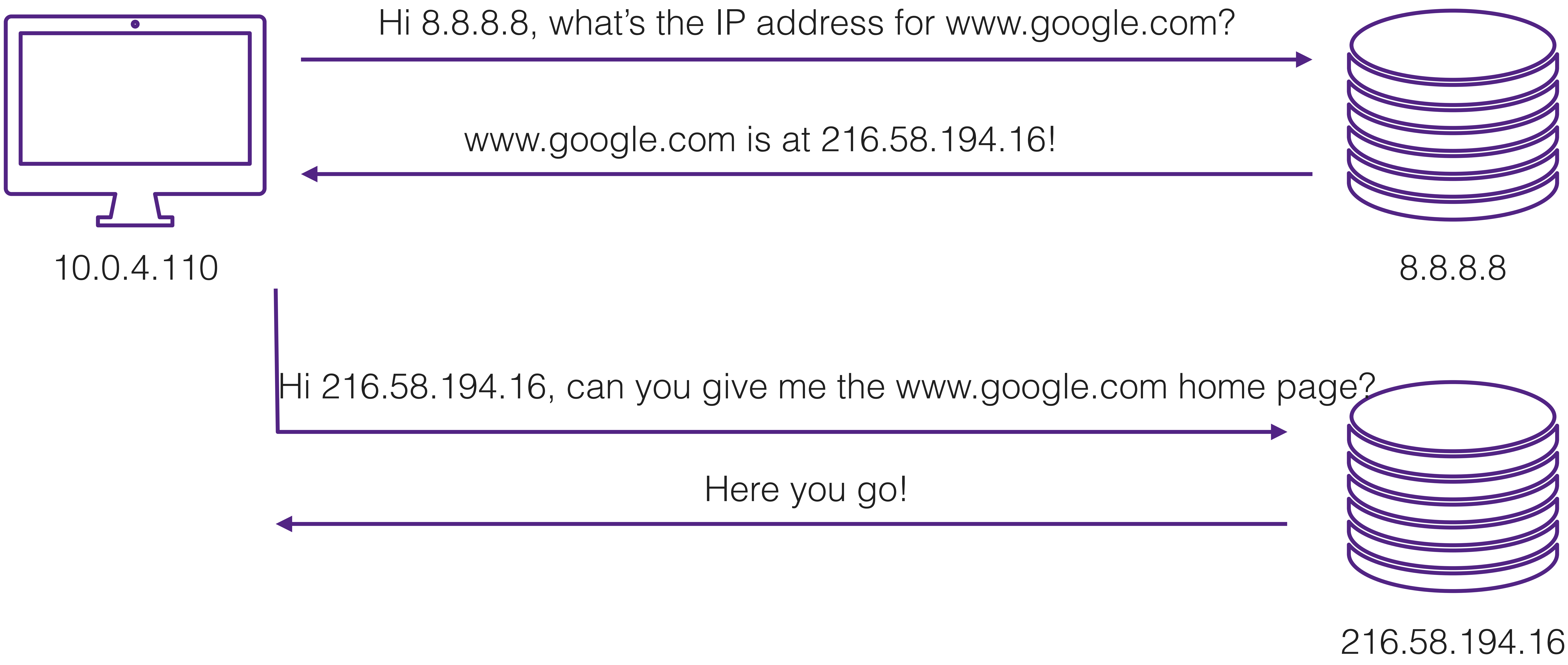
August 4, 2021

IP addresses

- Every computer on a network has an "IP address" uniquely identifying it on the network
  - An IPv4 address is 4 bytes. Usually written as 4 numbers, 0-255, separated by periods (e.g 192.168.1.230)
- If you want to talk to a computer, you need to know its IP address
- How do you find the IP address? (Too hard to remember!)
  - Your computer is configured with the address of a *DNS server* (can be hardcoded)
  - When you want to reach "www.google.com," ask the DNS server for the IP address
  - IP address of www.google.com:

```
🍌 dig +noall +answer www.google.com
www.google.com.        204    IN    A    216.58.194.16
```

DNS resolution



Understanding port numbers

“Host” (computer) = apartment complex

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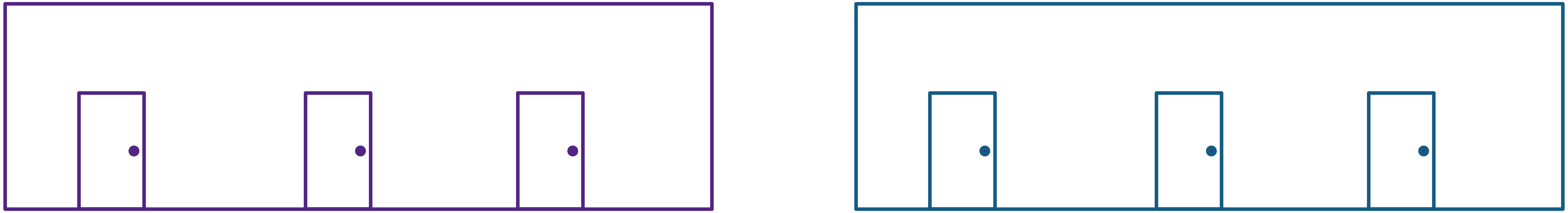
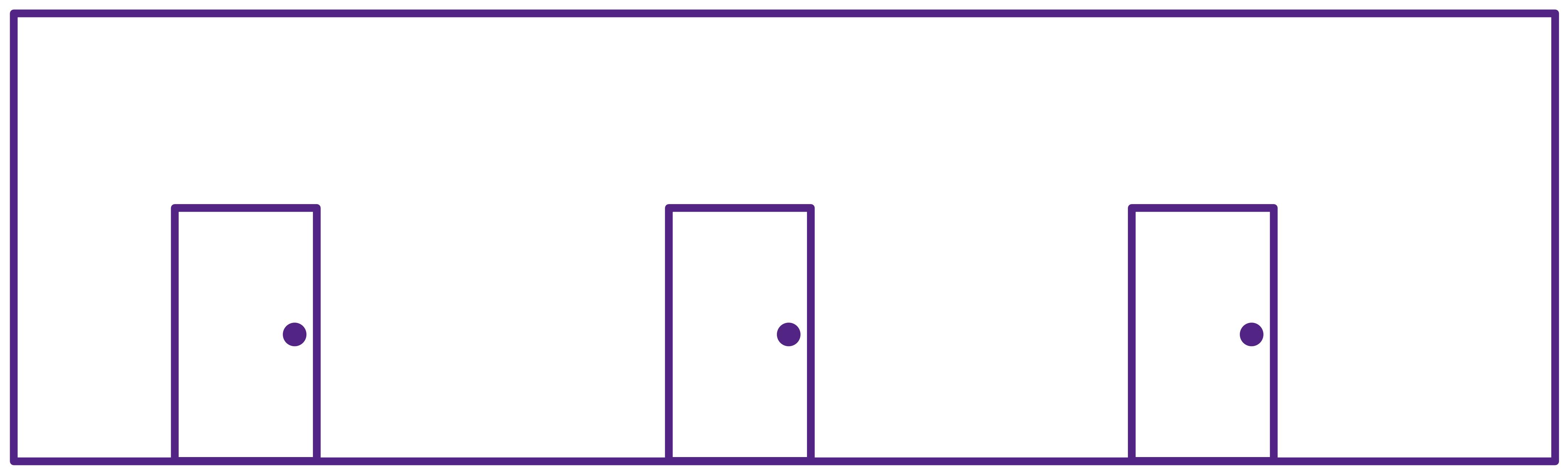
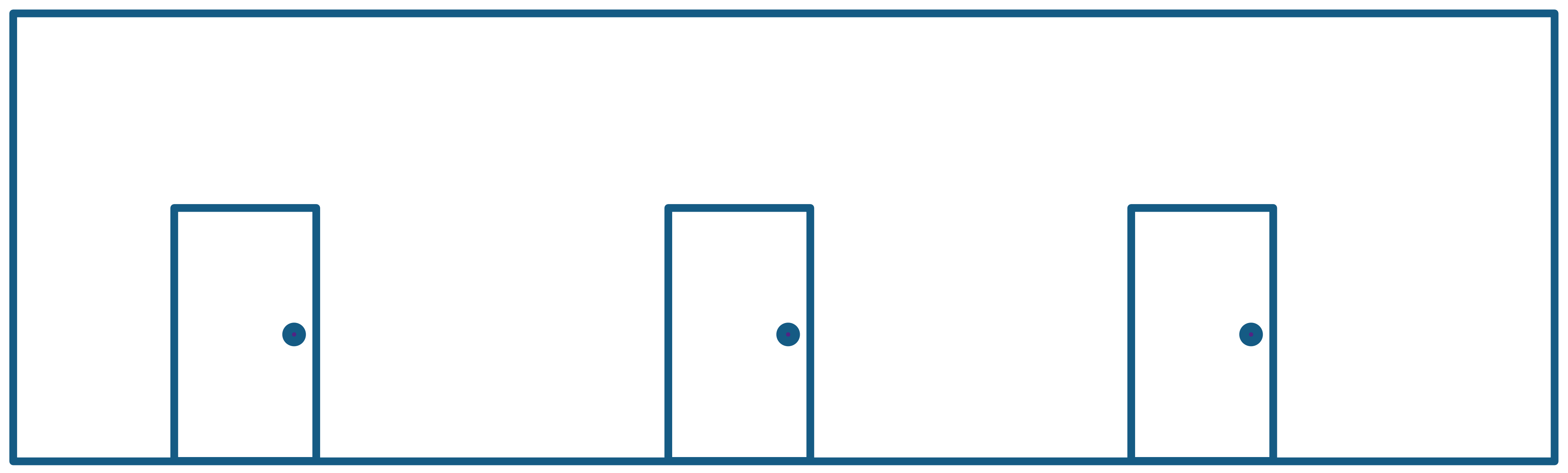


“Host” (computer) = apartment complex

“IP address” = apartment complex address





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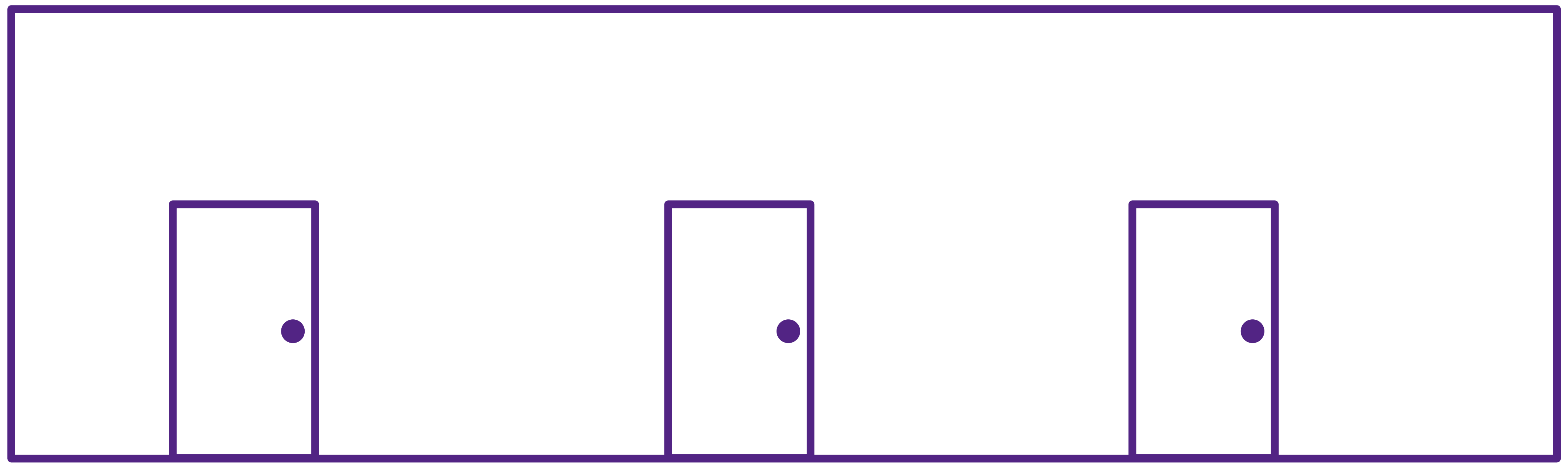
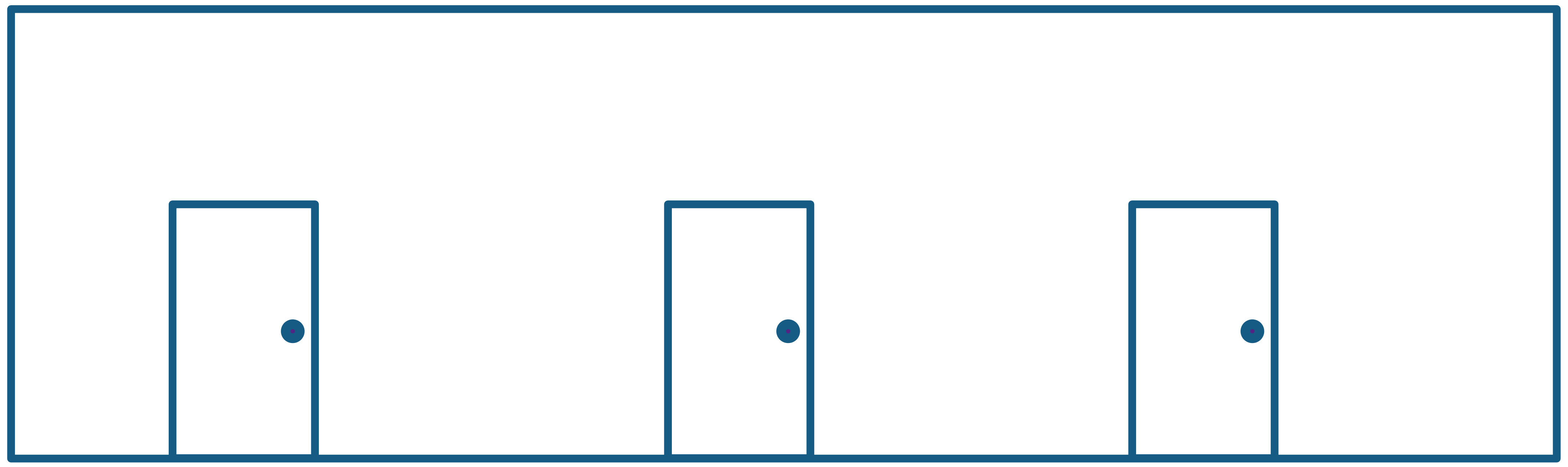
171.67.215.200



10.0.4.128



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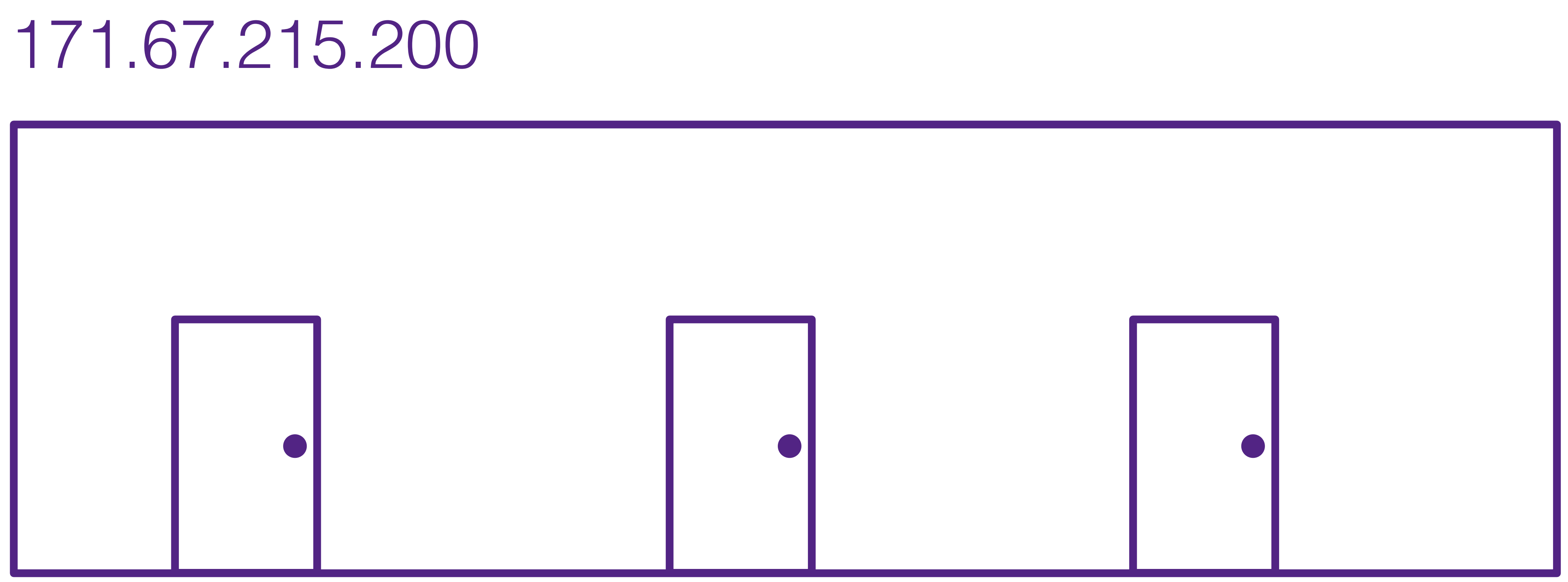

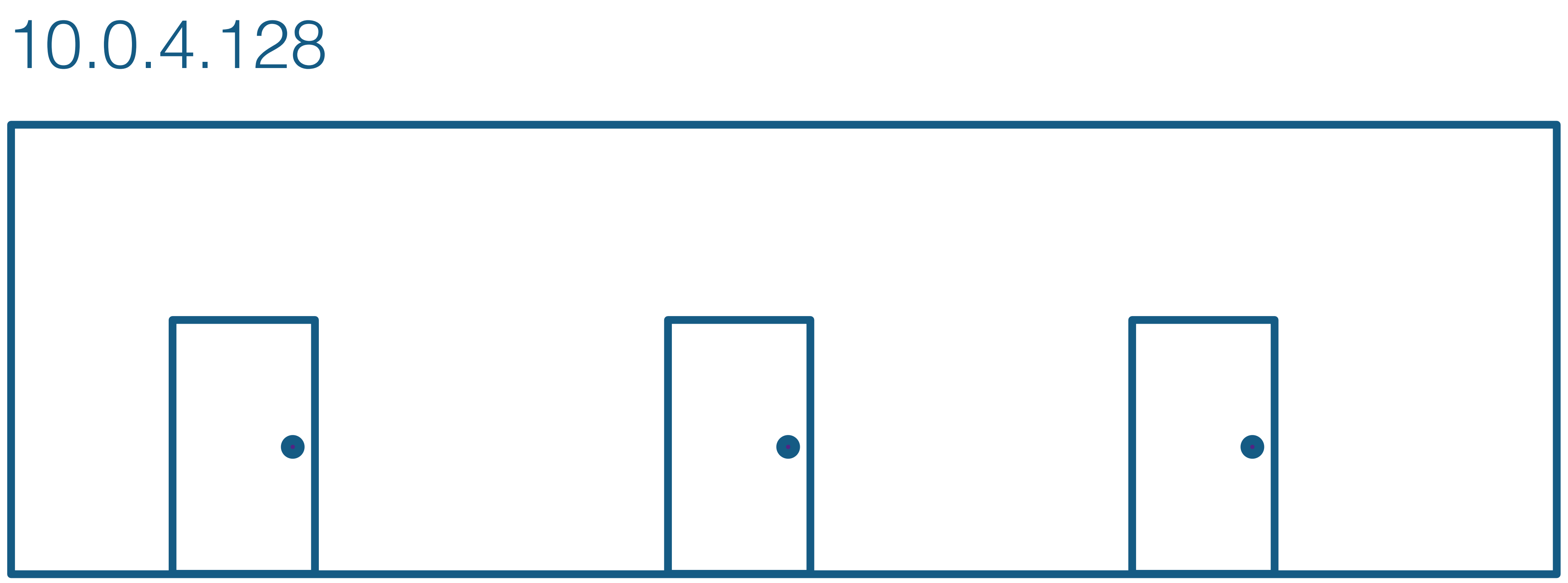

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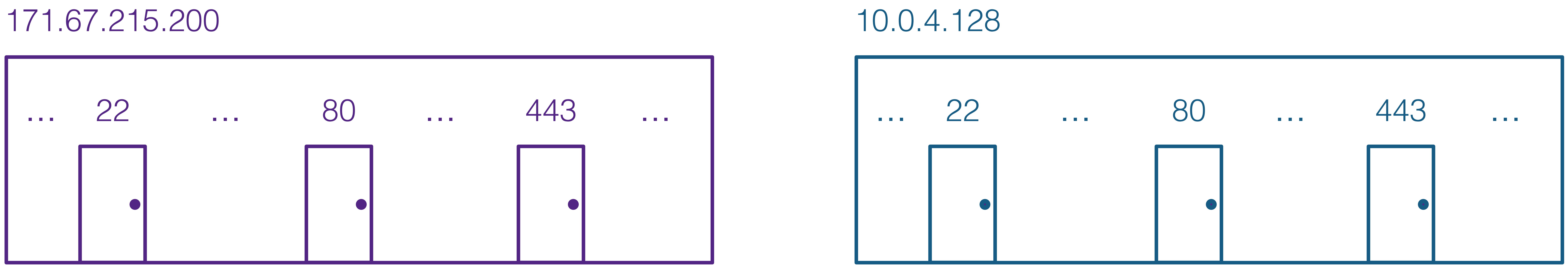

Want to go to http://web.stanford.edu?

Use DNS to find web.stanford.edu's IP address: 171.67.215.200

Go to that apartment complex

Knock on the apartment that runs the HTTP service (port 80)

“Host” (computer) = apartment complex

“IP address” = apartment complex address

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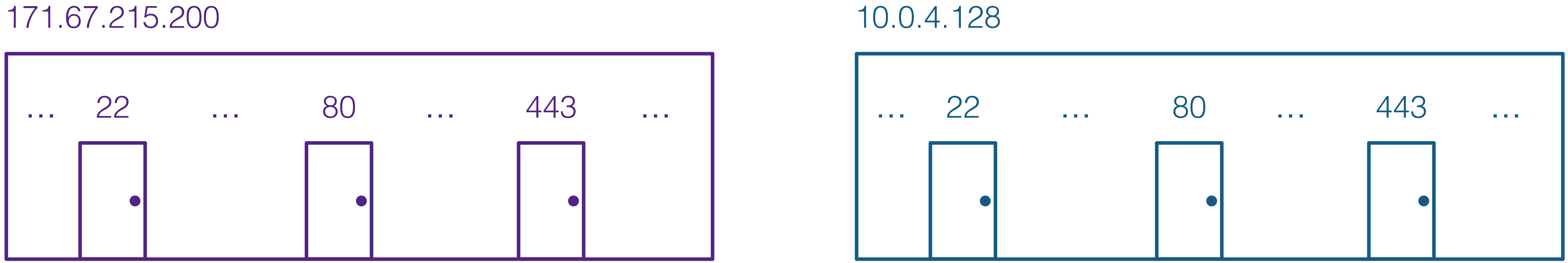


Want to SSH into myth.stanford.edu?

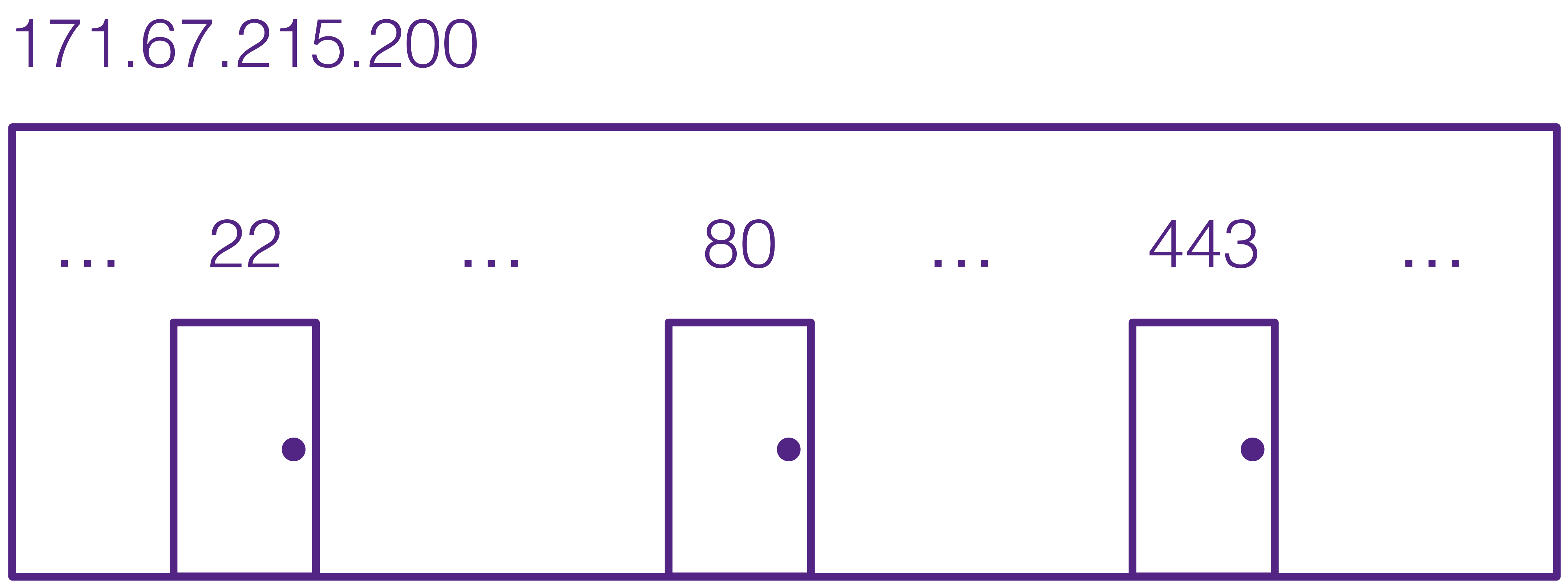
Use DNS to find myth.stanford.edu's IP address: 171.64.15.29

Go to that apartment complex

Knock on the apartment that runs the SSH service (port 22)

Starting a server

Apartment complex = host



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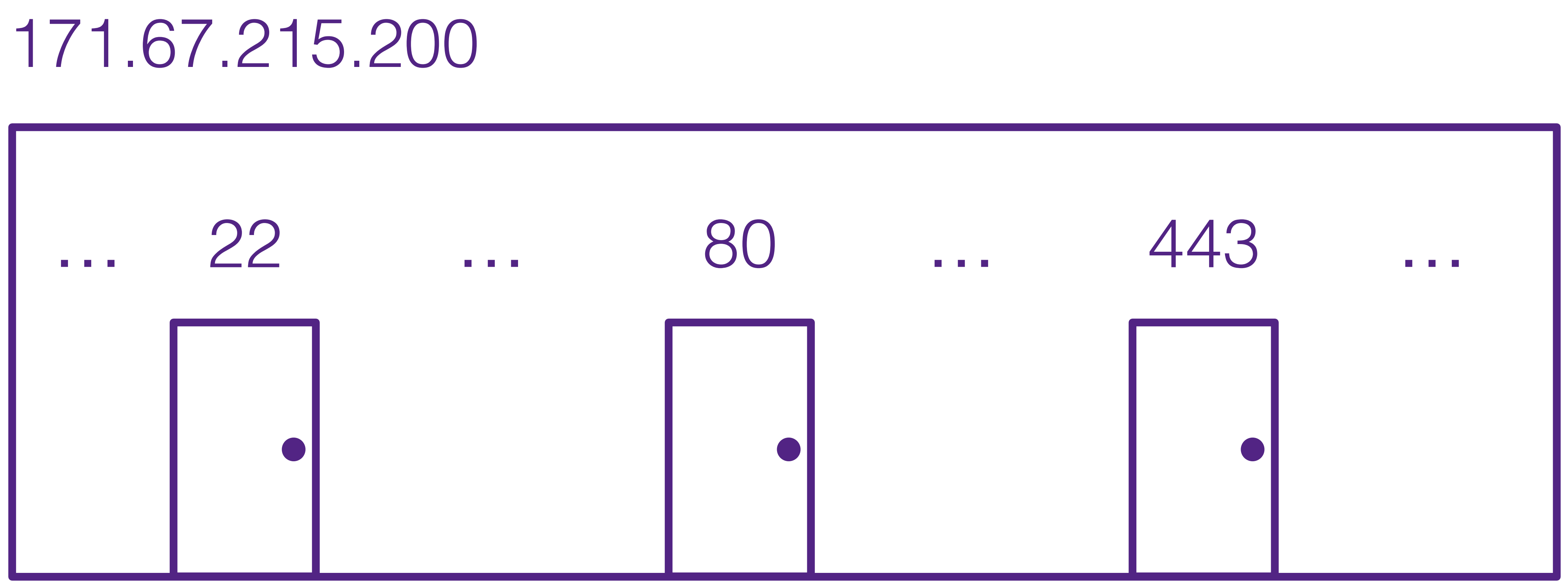
Each host will have some processes running on it



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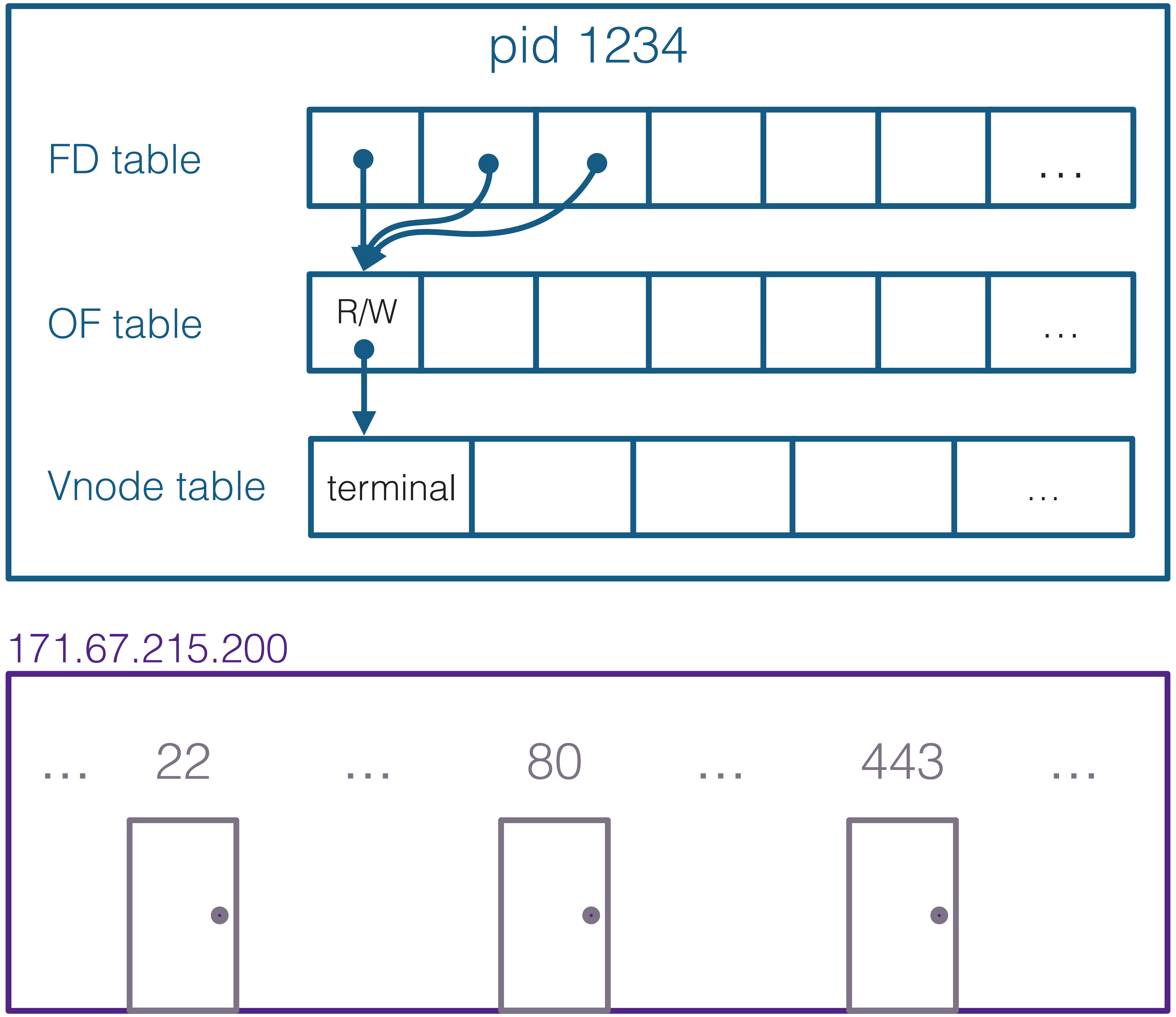

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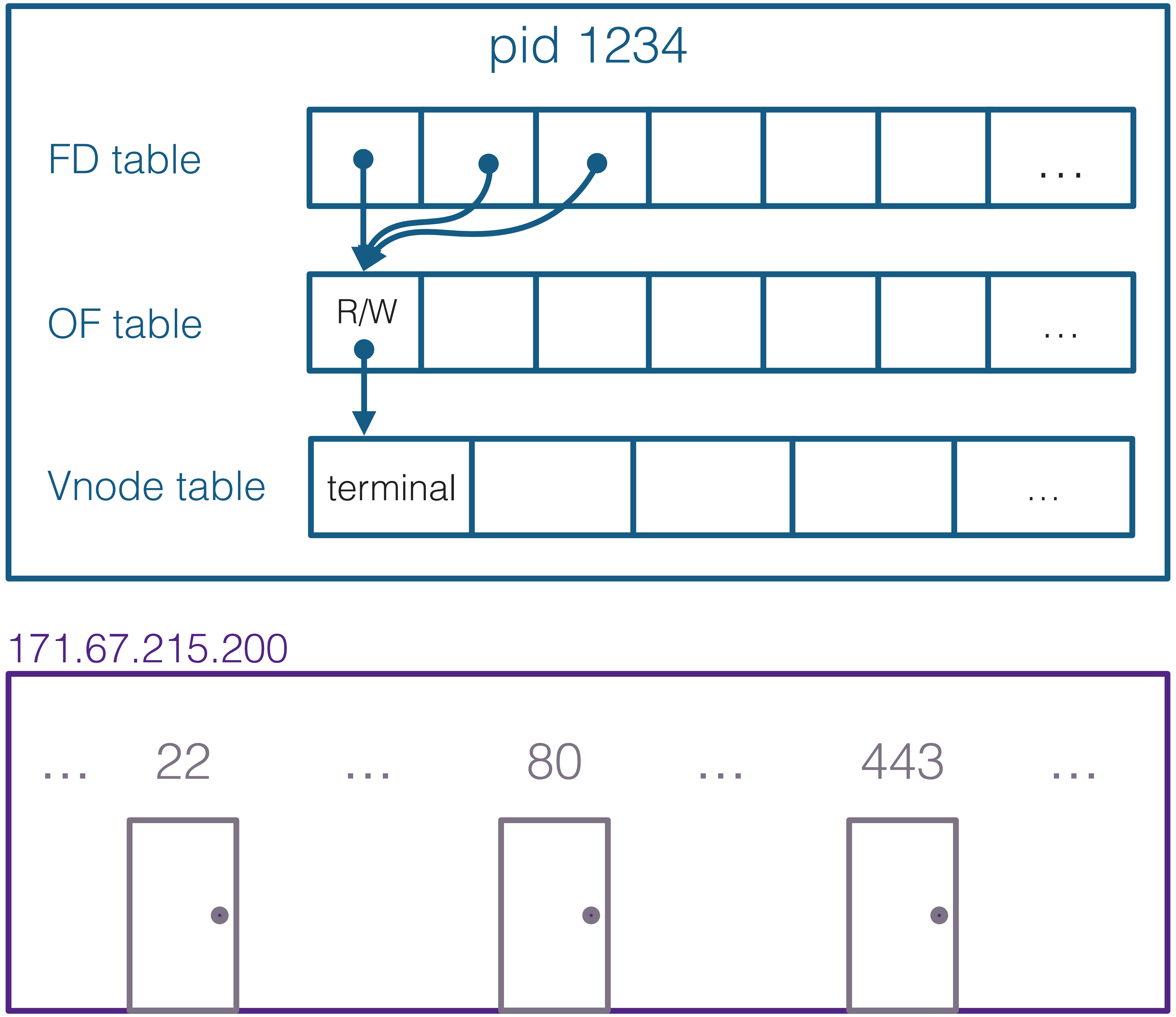

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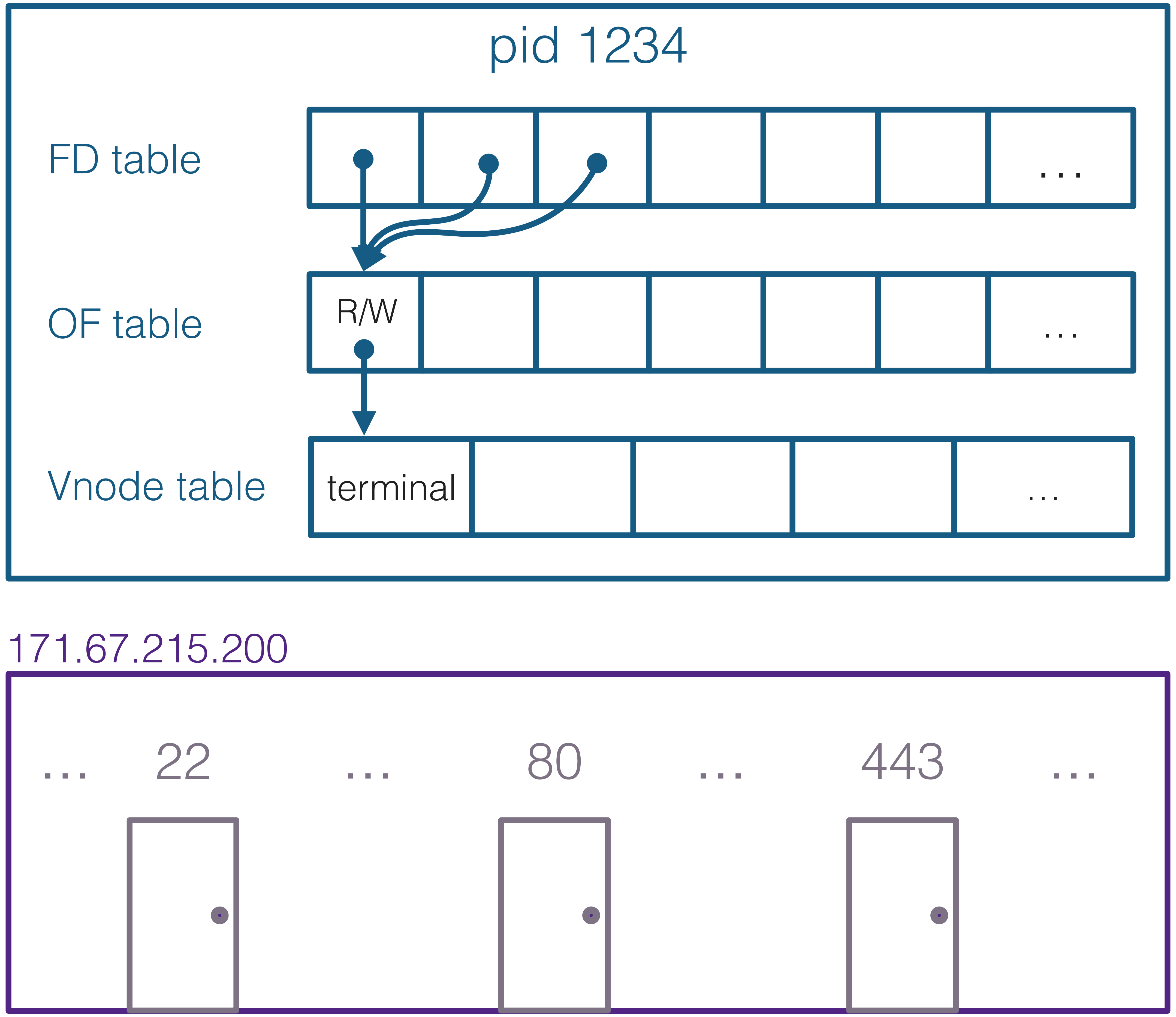
Process “sets up shop” in an apartment. (Only one process per apartment)



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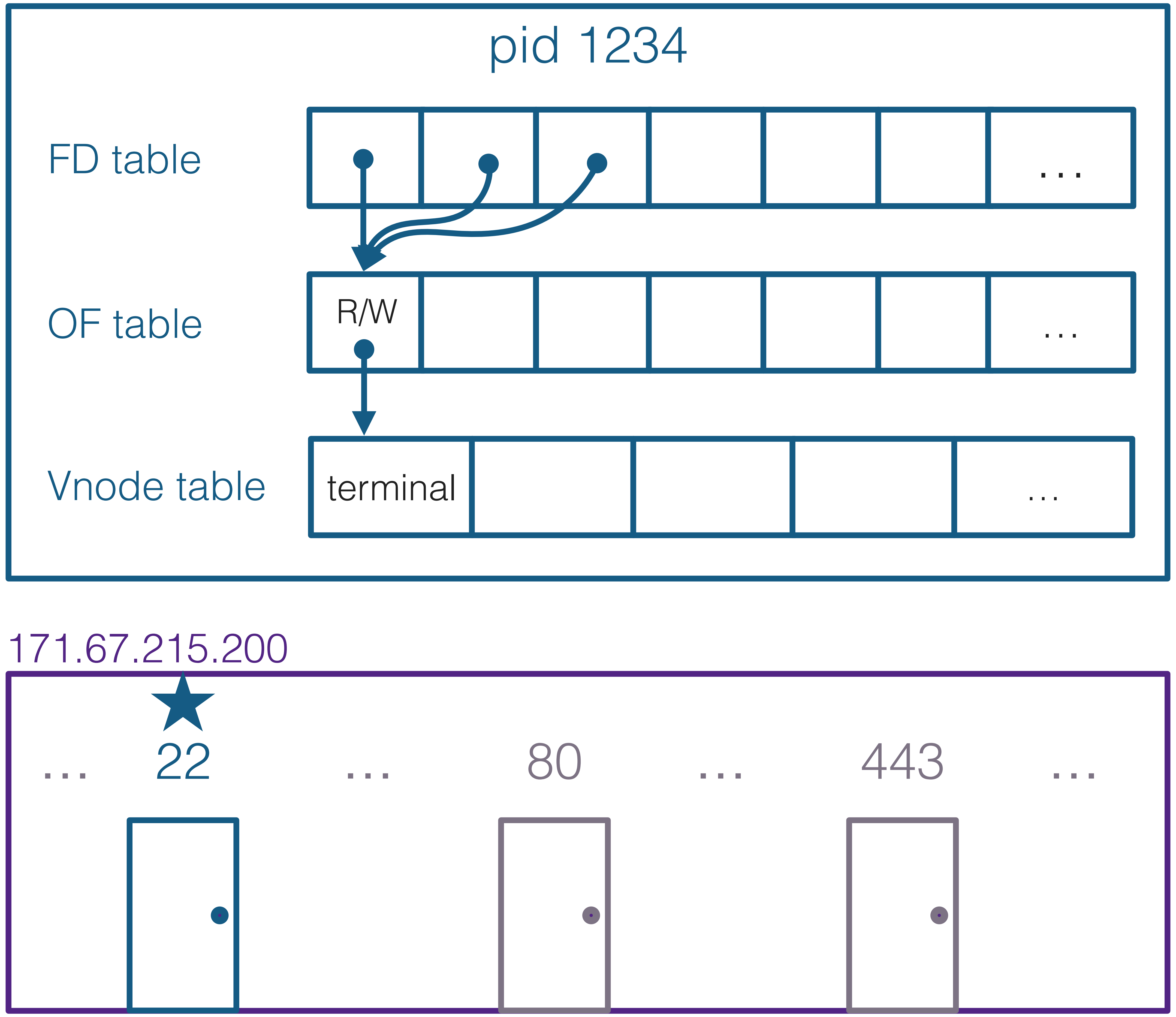

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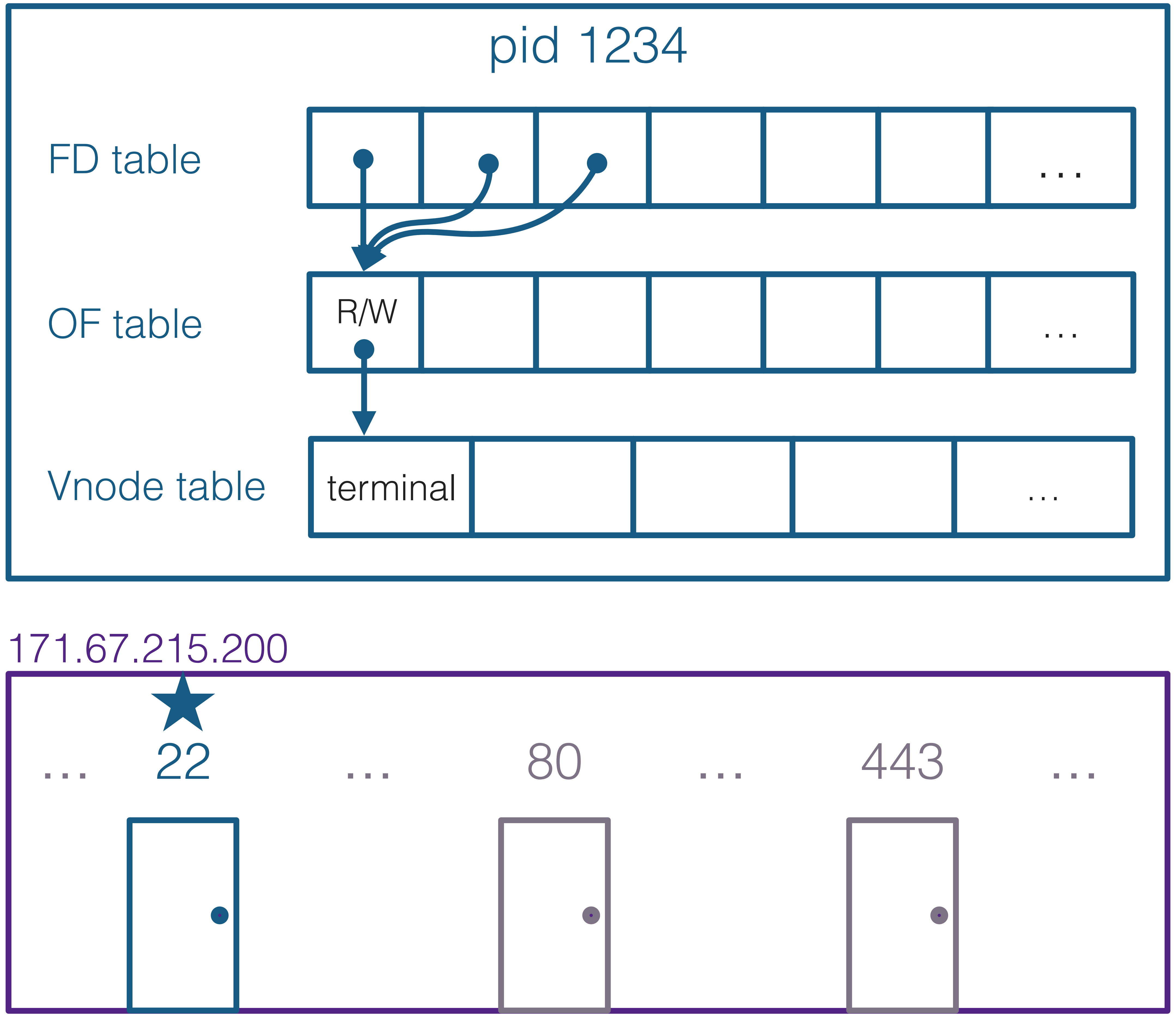

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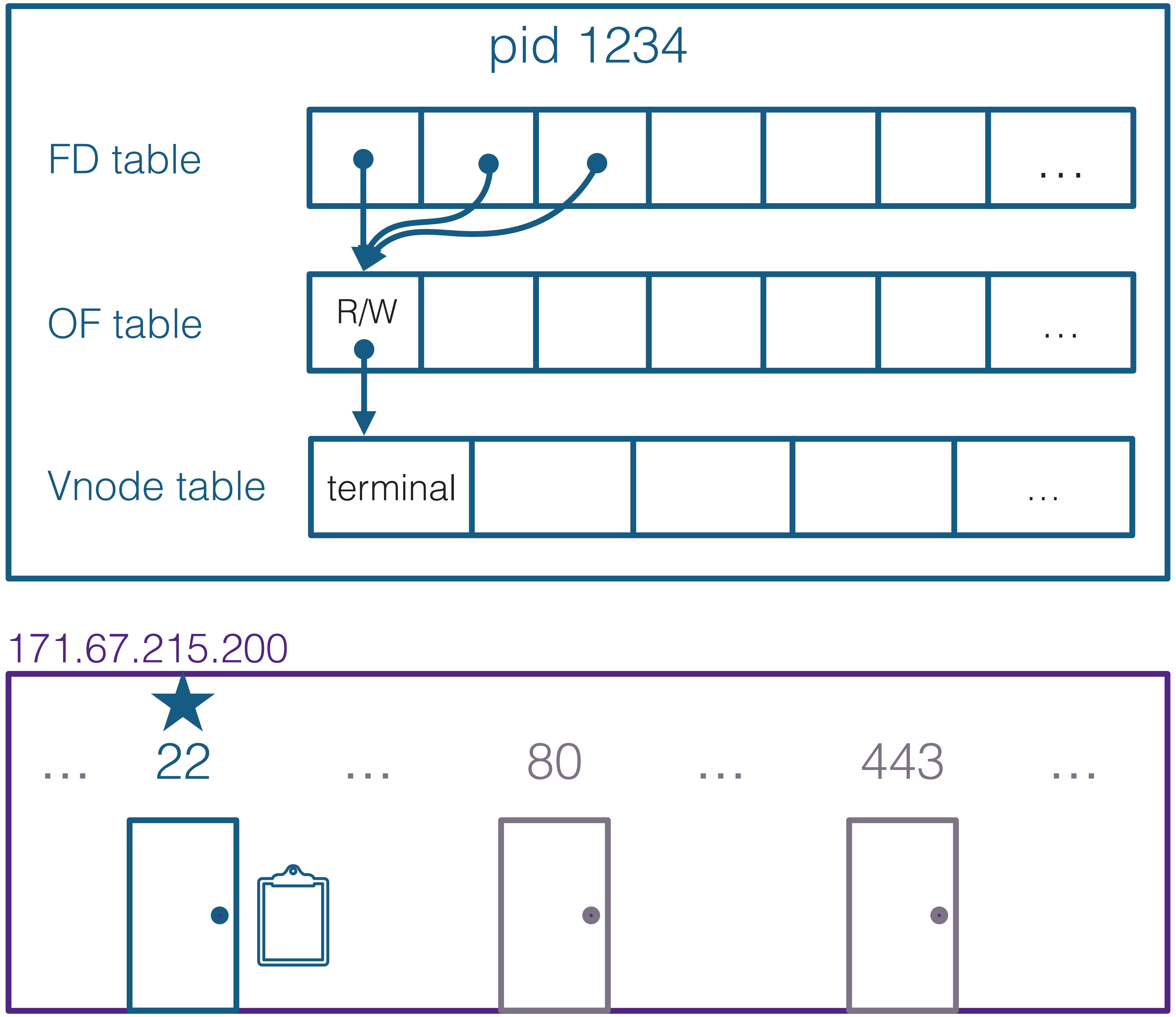

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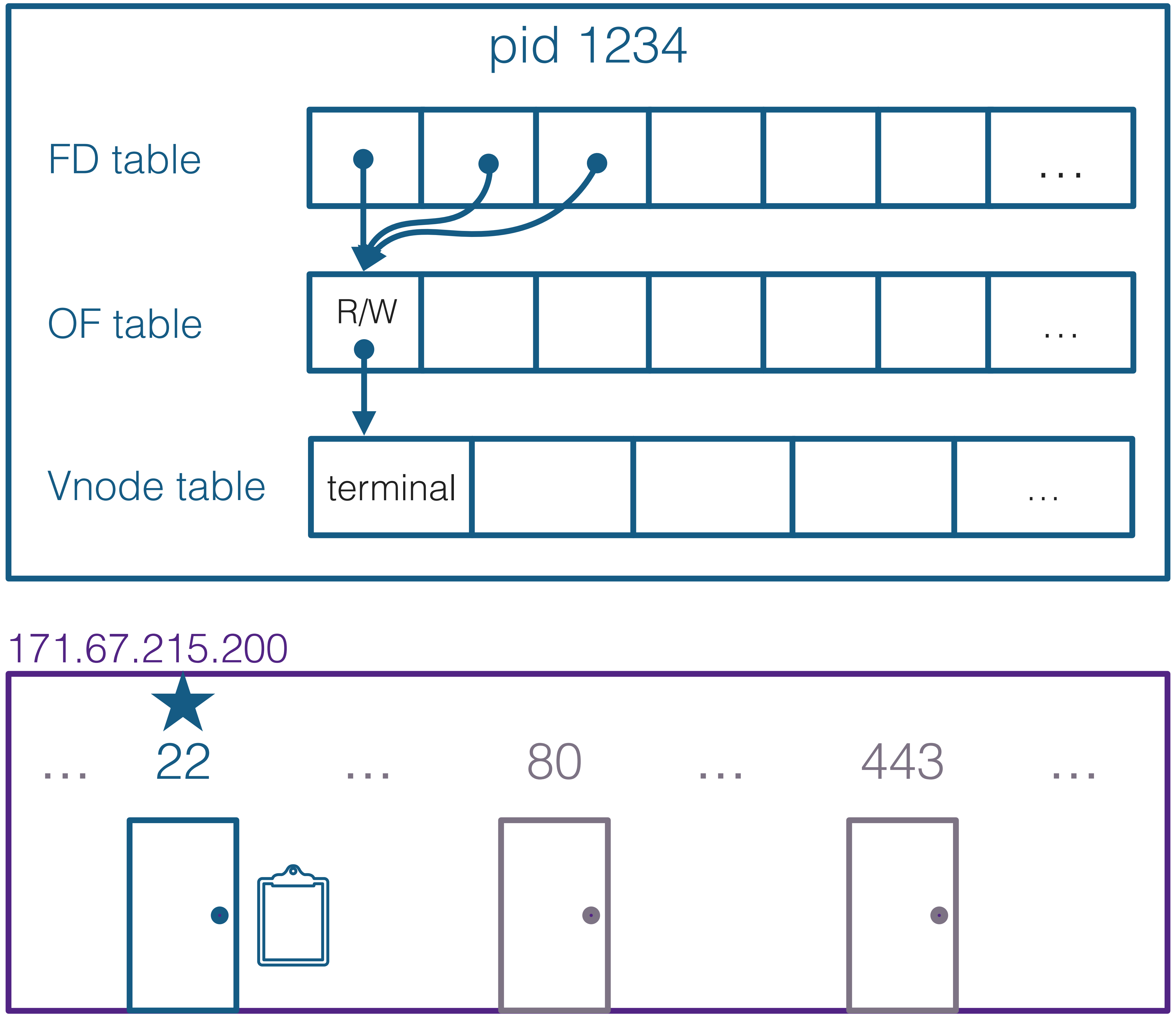
Waiting list is attached to a file descriptor, so the process can see when someone arrives



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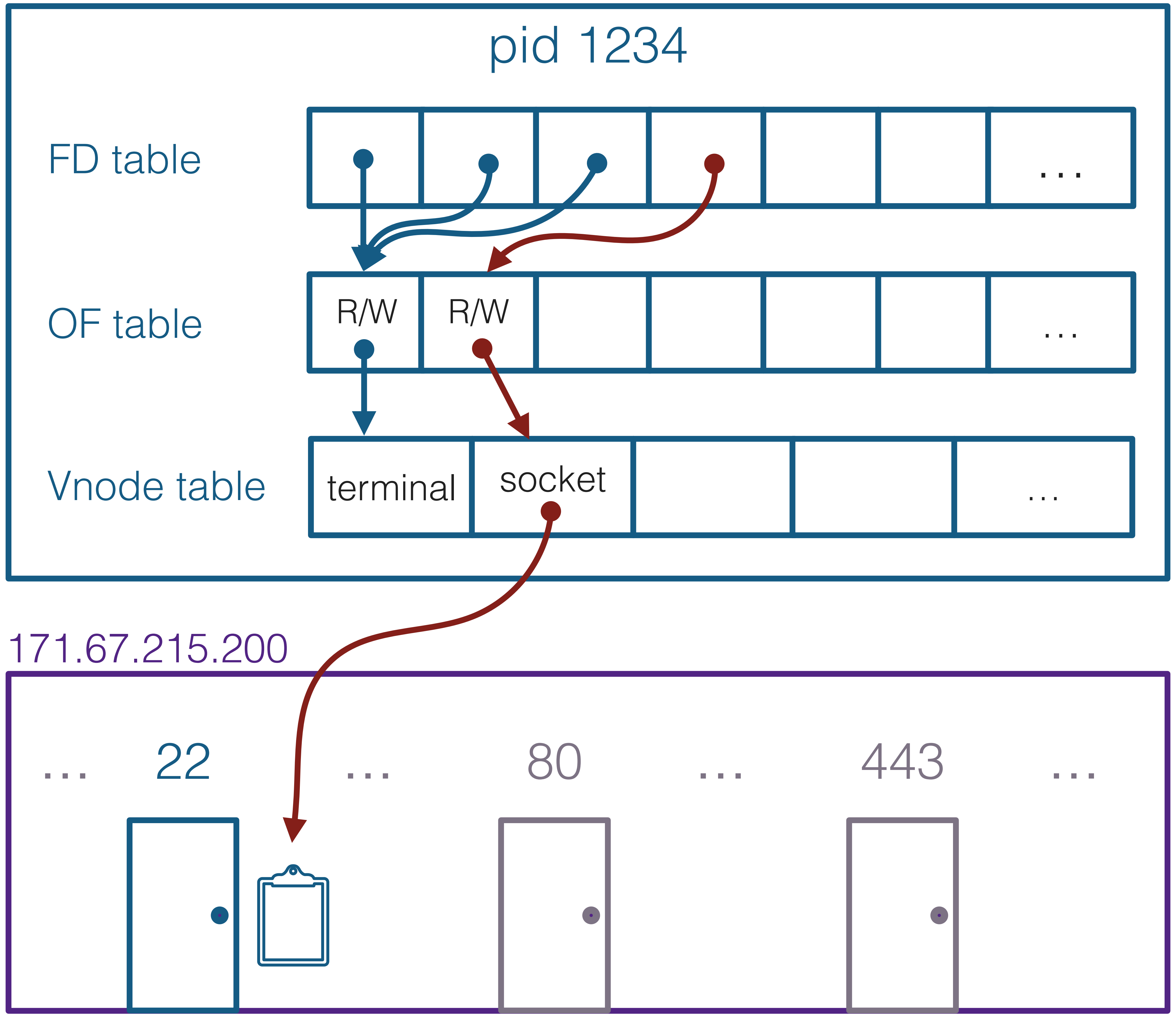
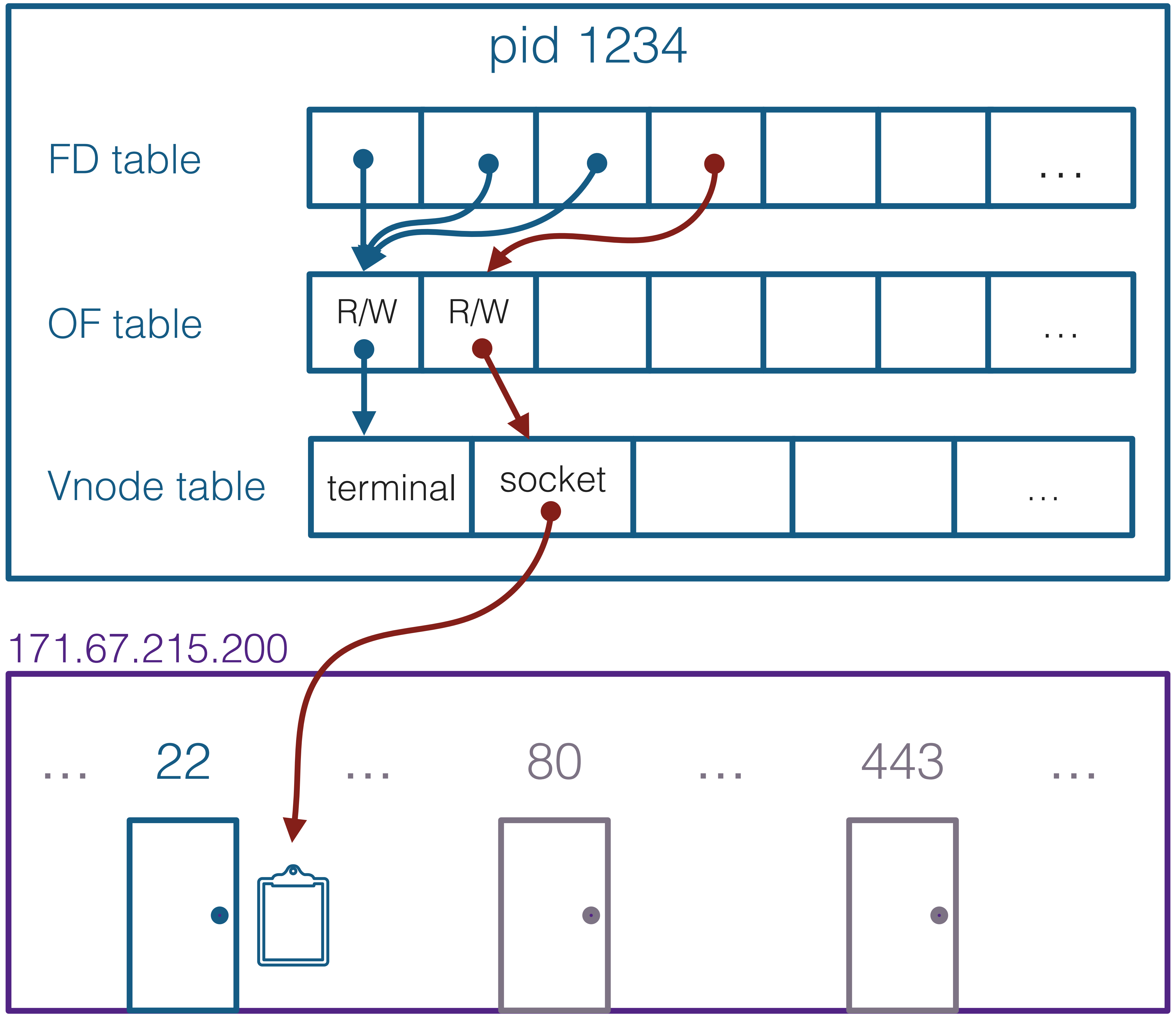


“Binding” to a port:

Other processes can bind to other ports

(no two processes can bind to the same port — one application per apartment!)



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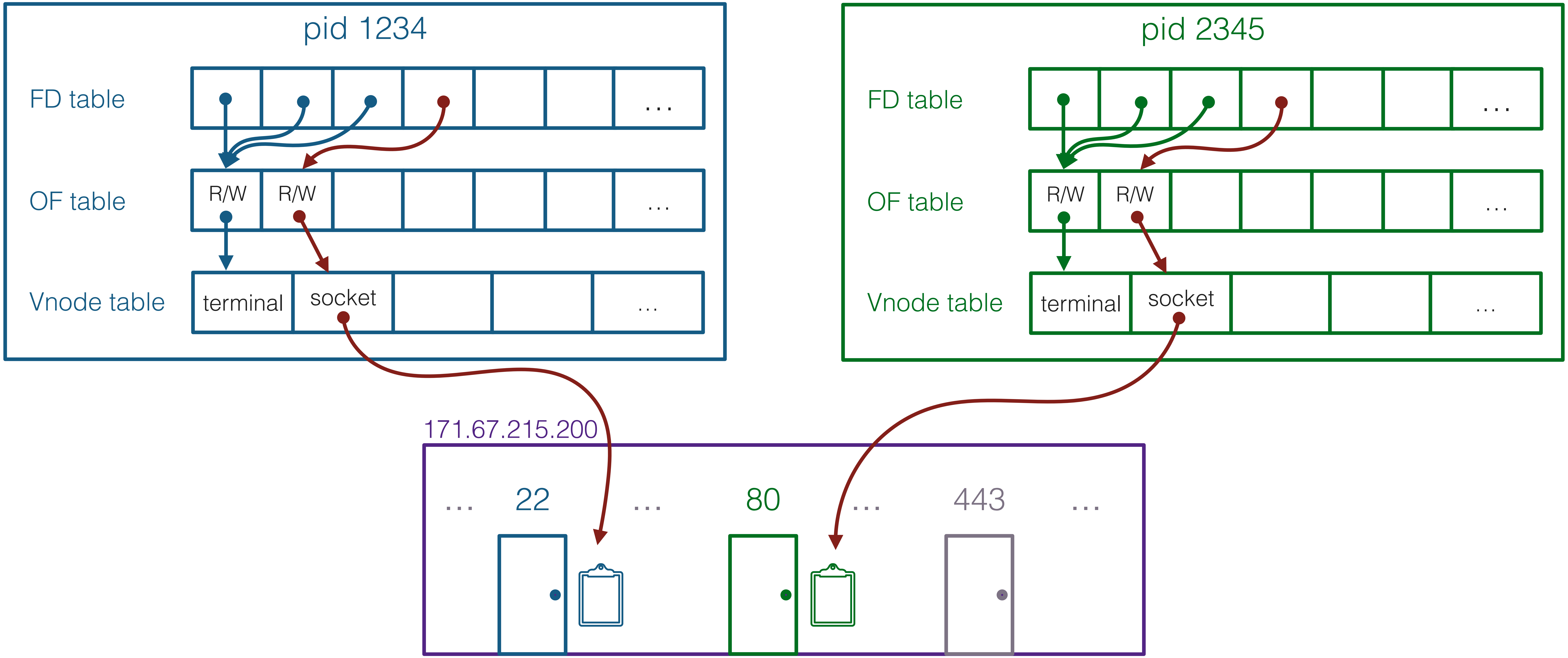
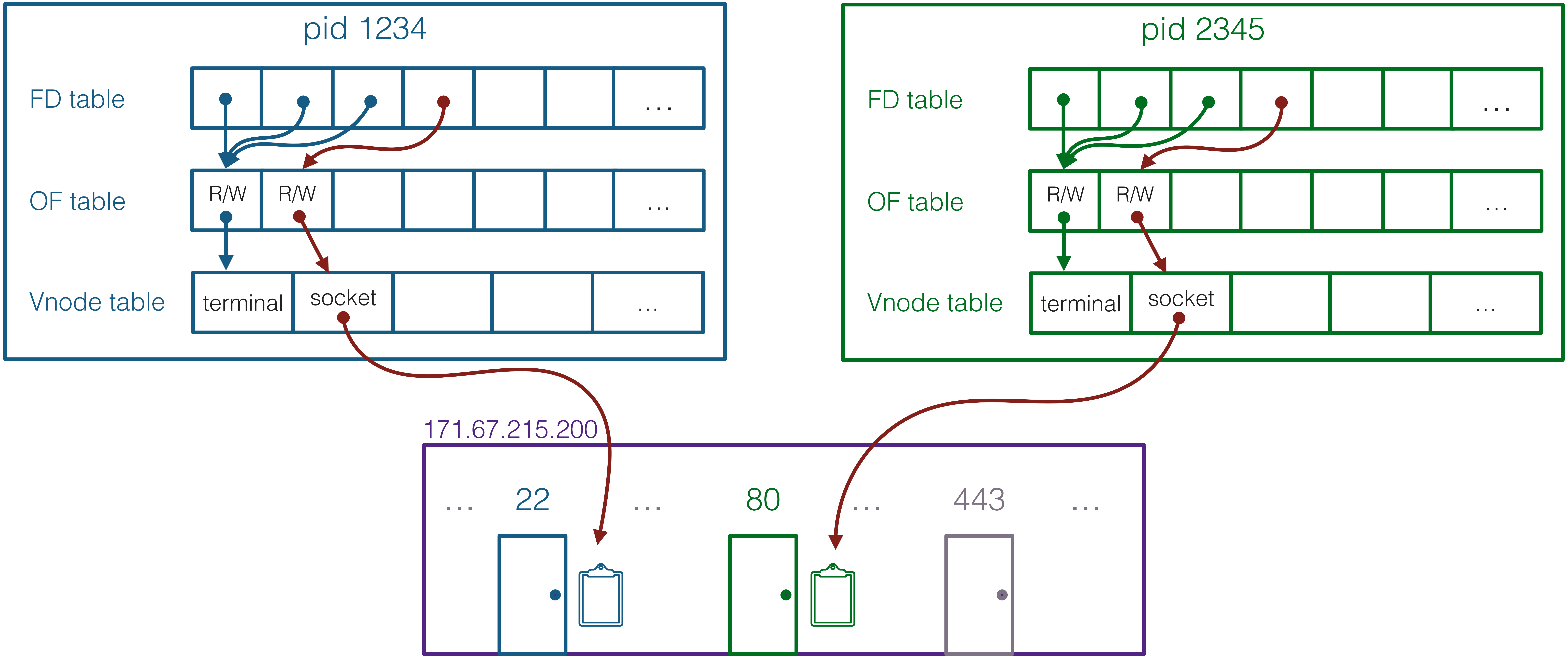


"Binding" to a port:

A process can bind to multiple ports, if it desires



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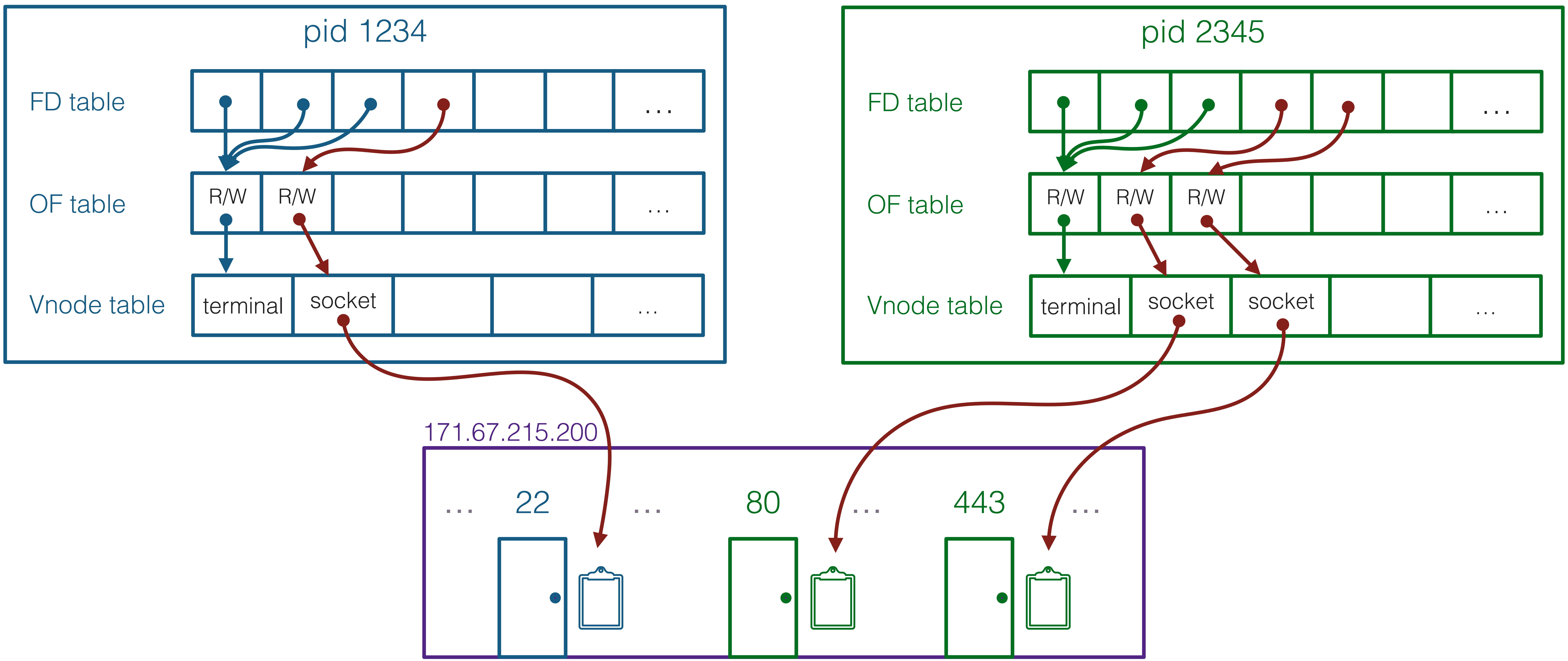
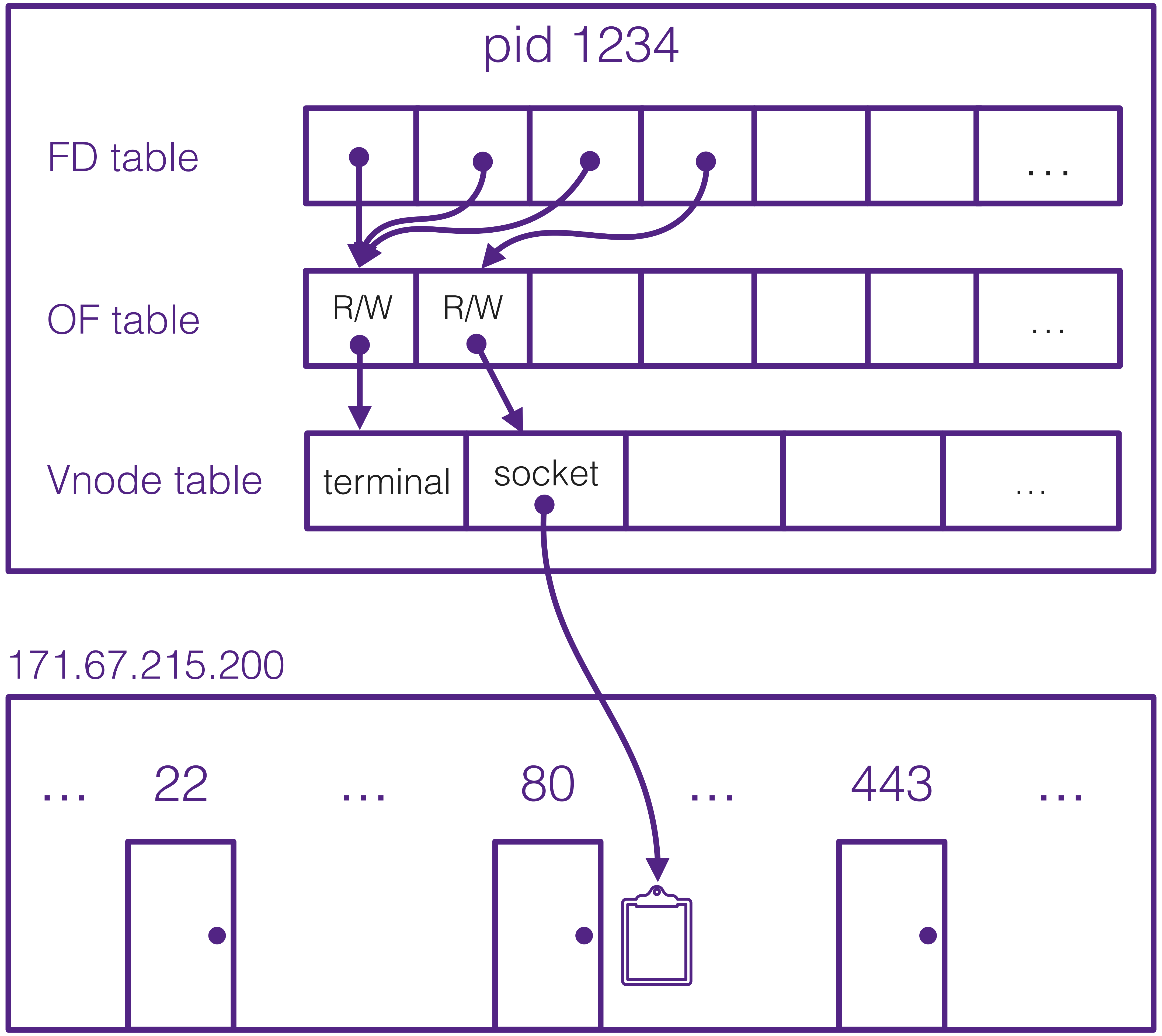
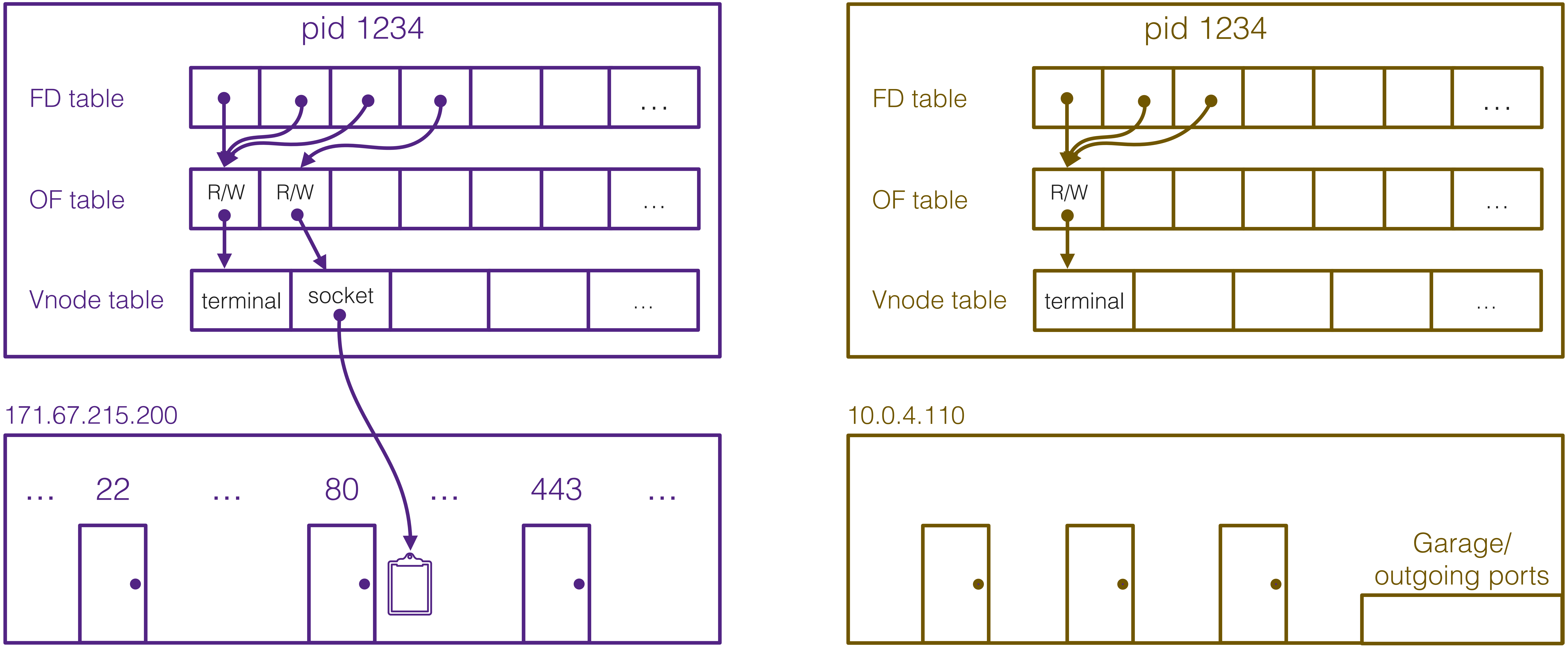


Connecting a client

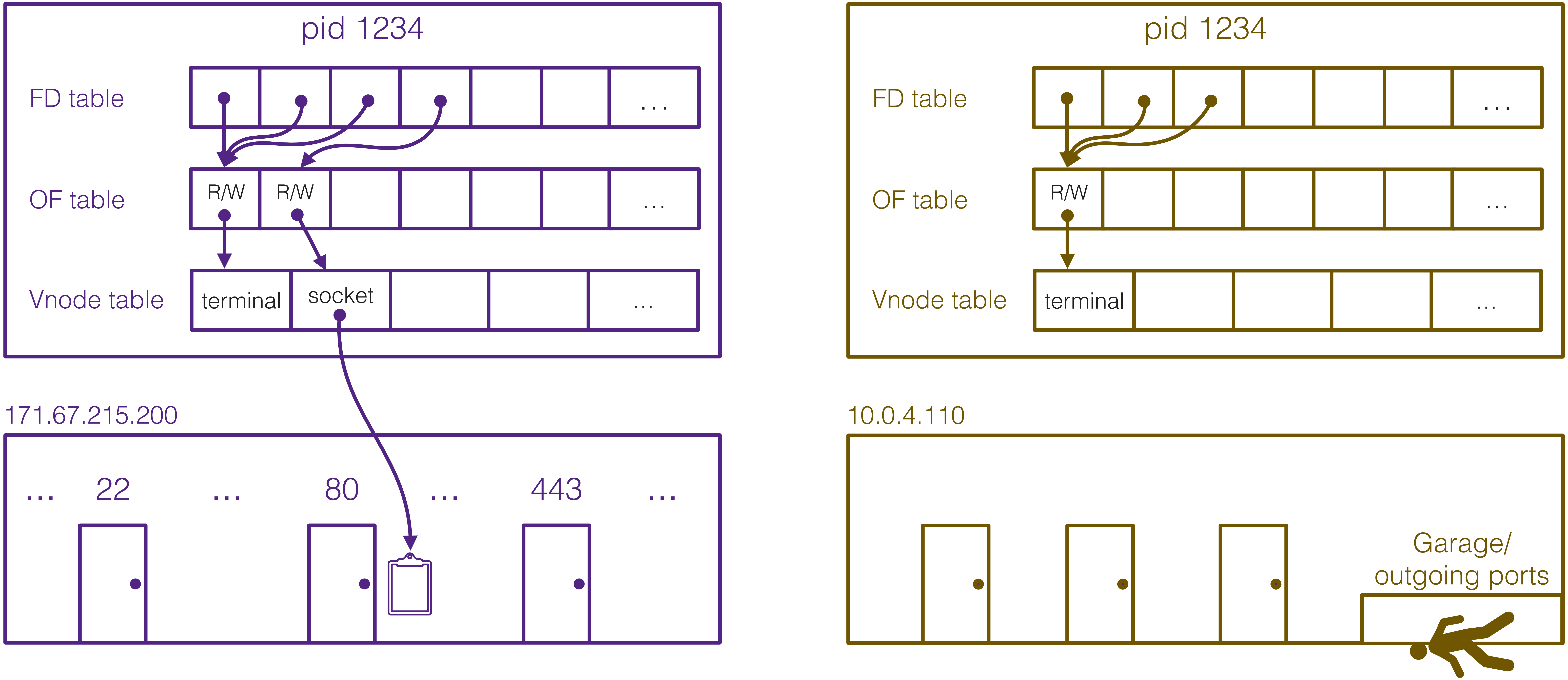
Say we have a server bound on 171.67.215.200:80



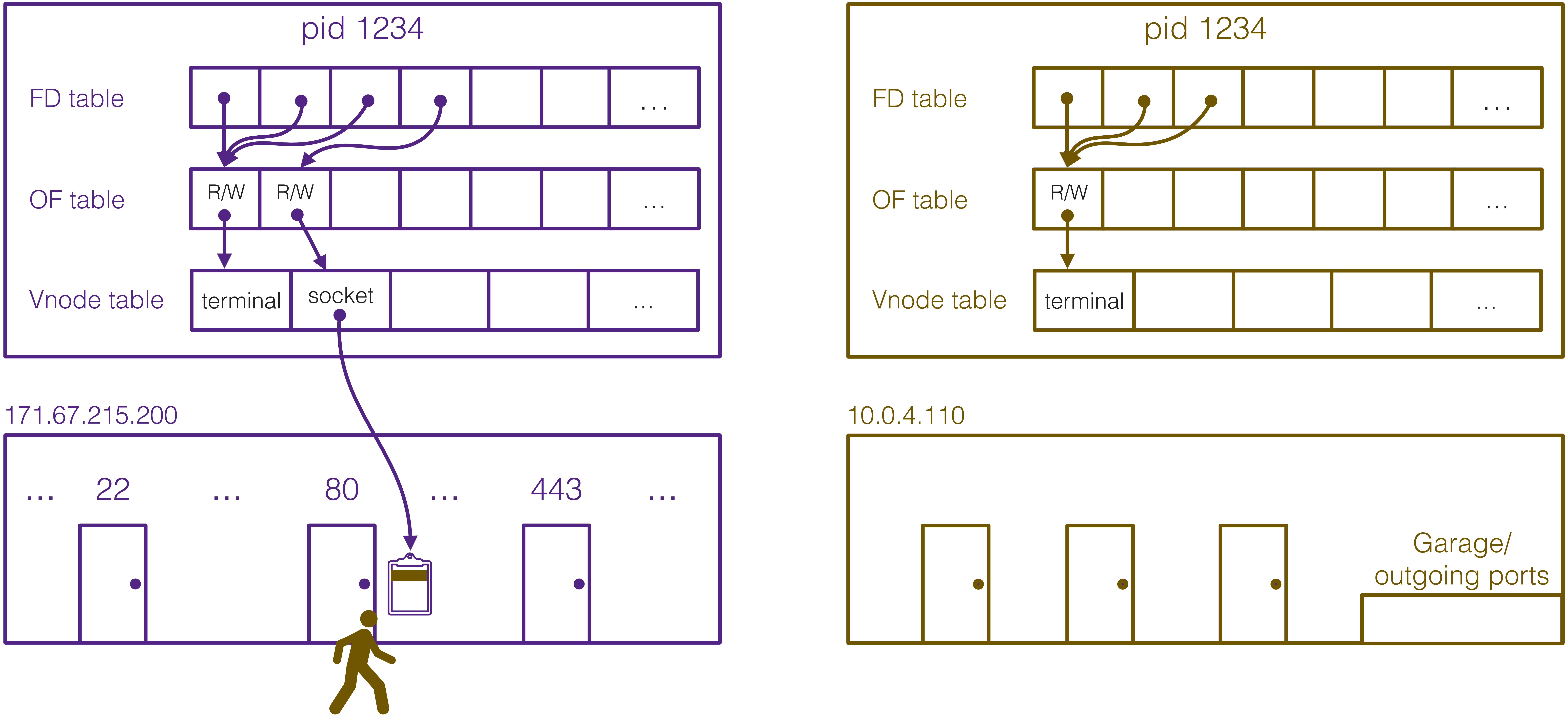
On some other computer, we want to talk to that server



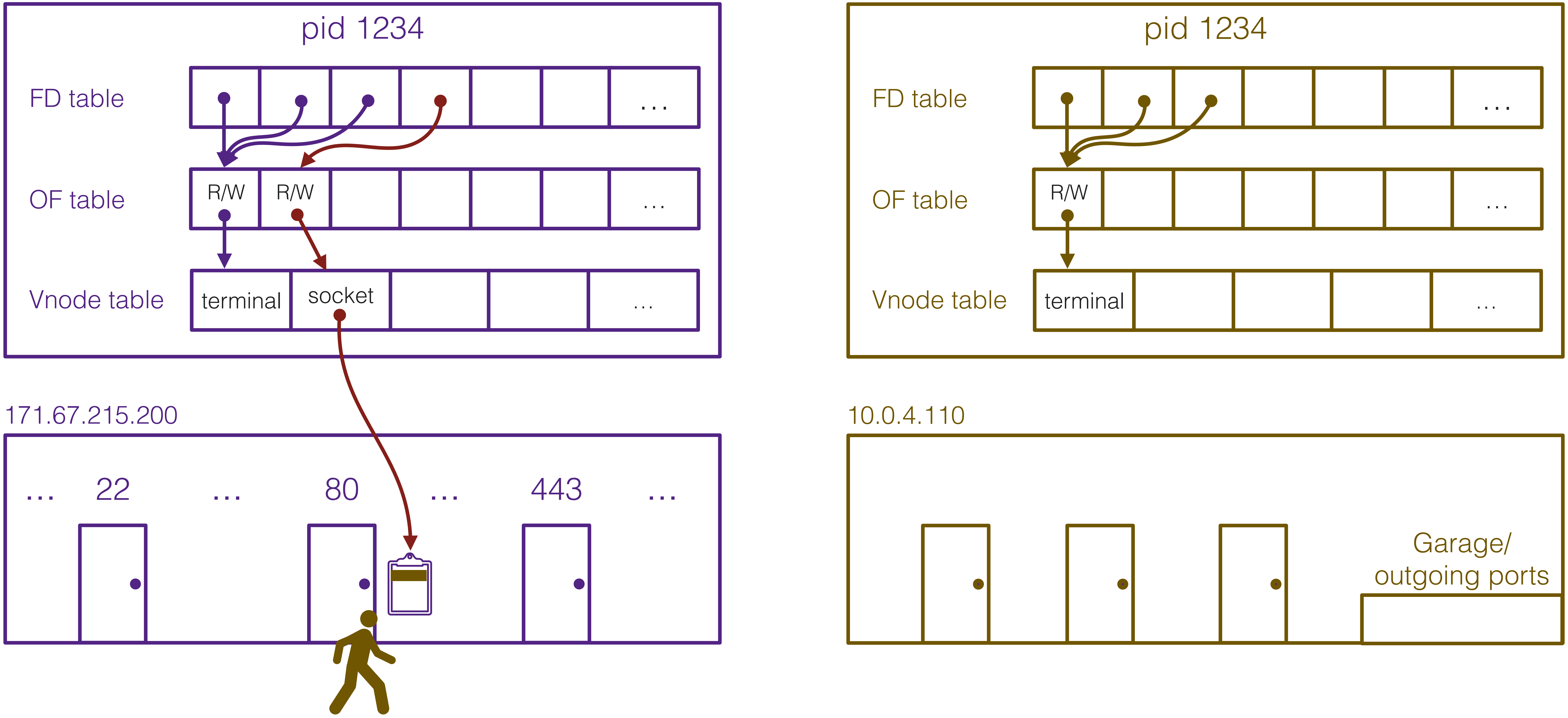
The “client” walks out to try to find 171.67.215.200:80



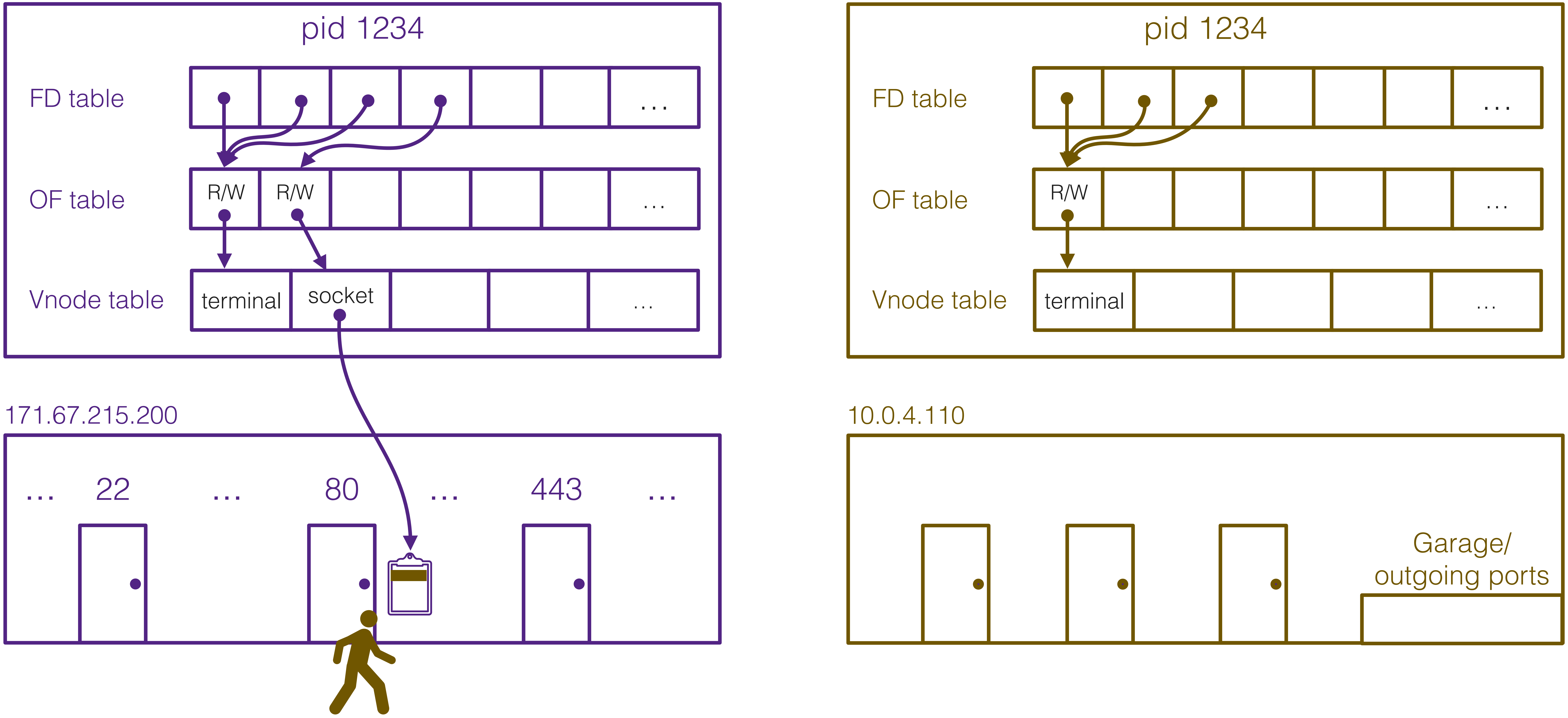
If successful, it adds itself to the waiting list



The server sees the client through its waiting list file descriptor



It takes the client off the waiting list and creates a new bidirectional "socket" that it can use to talk directly with the client



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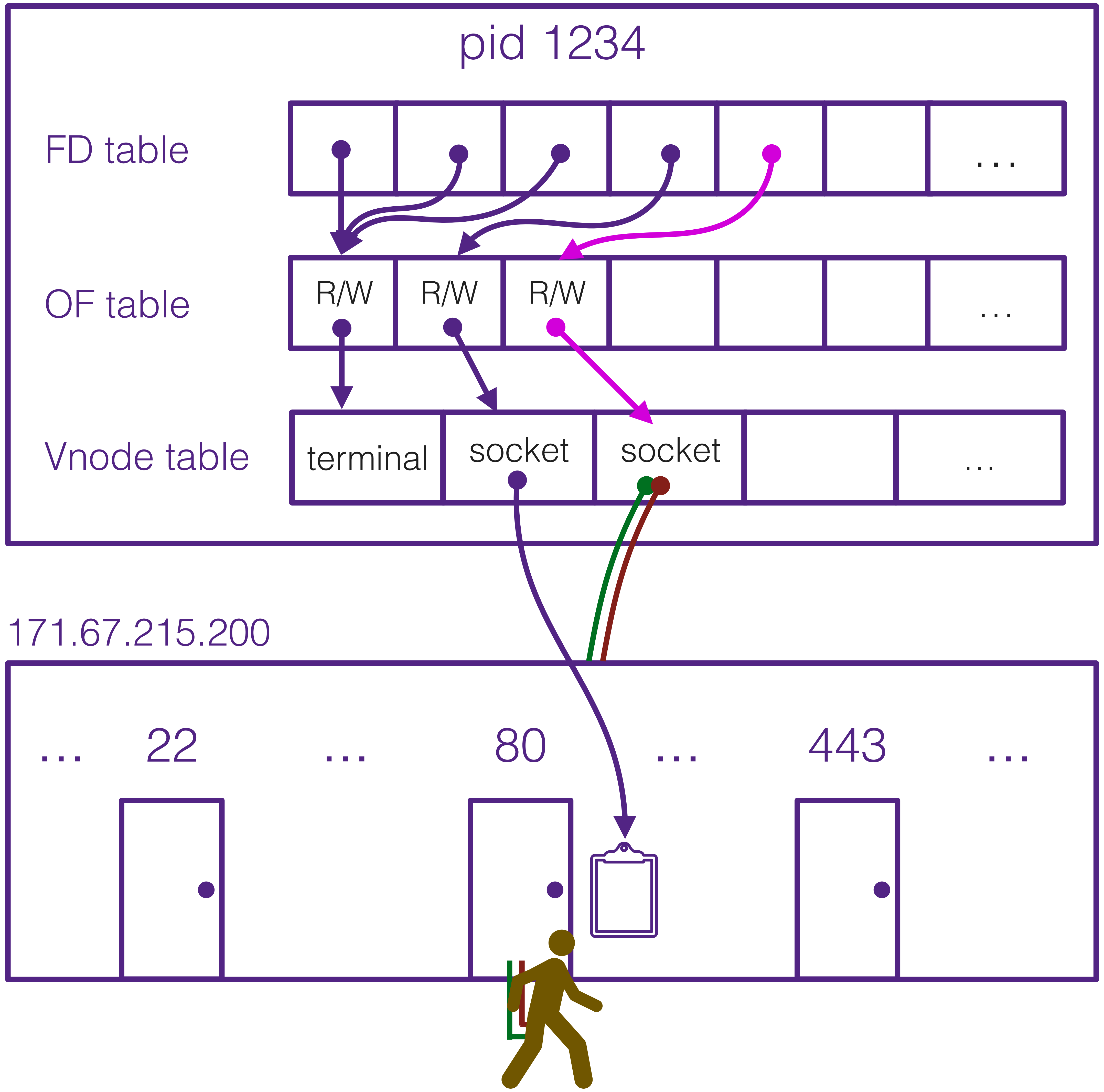
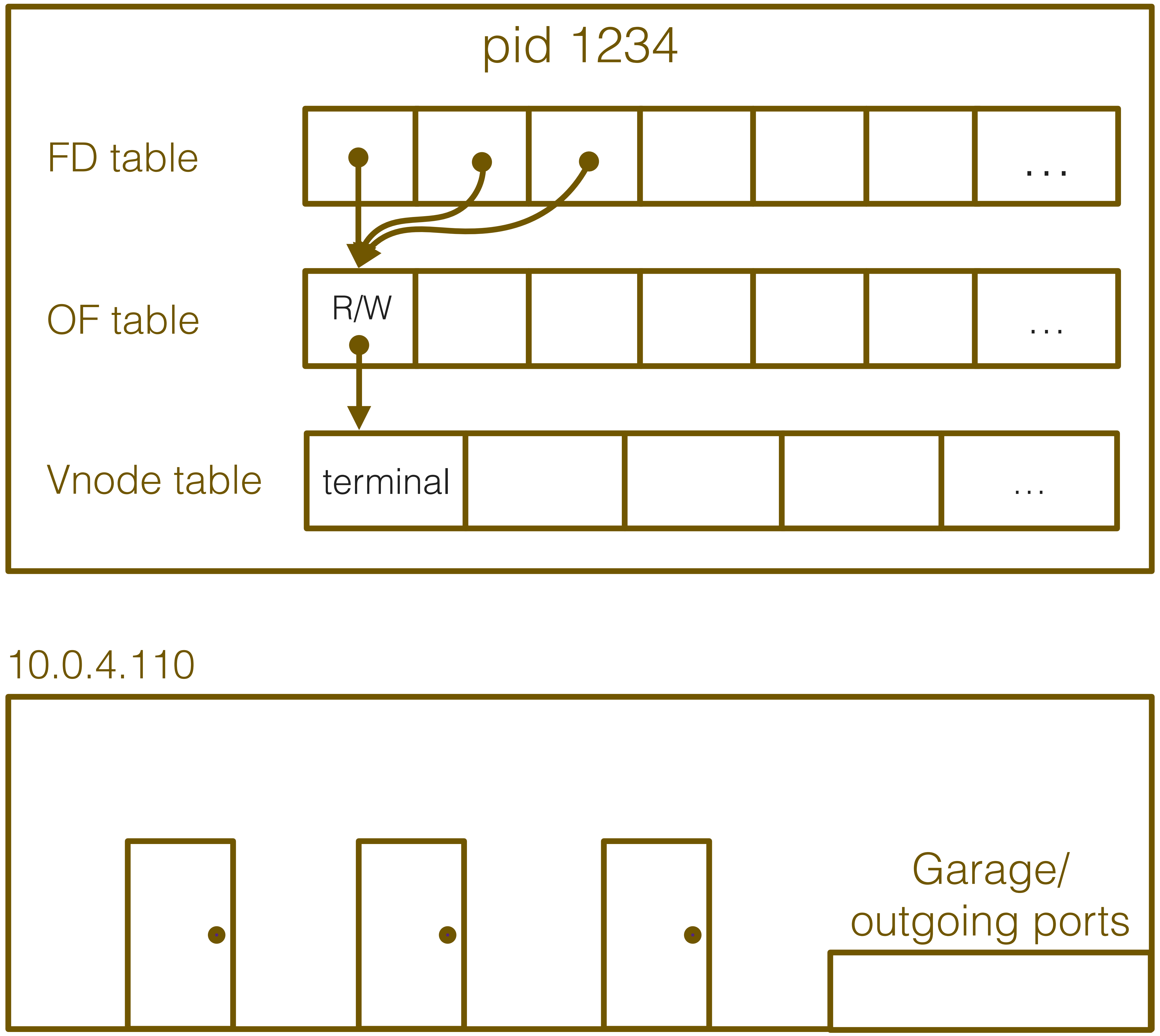
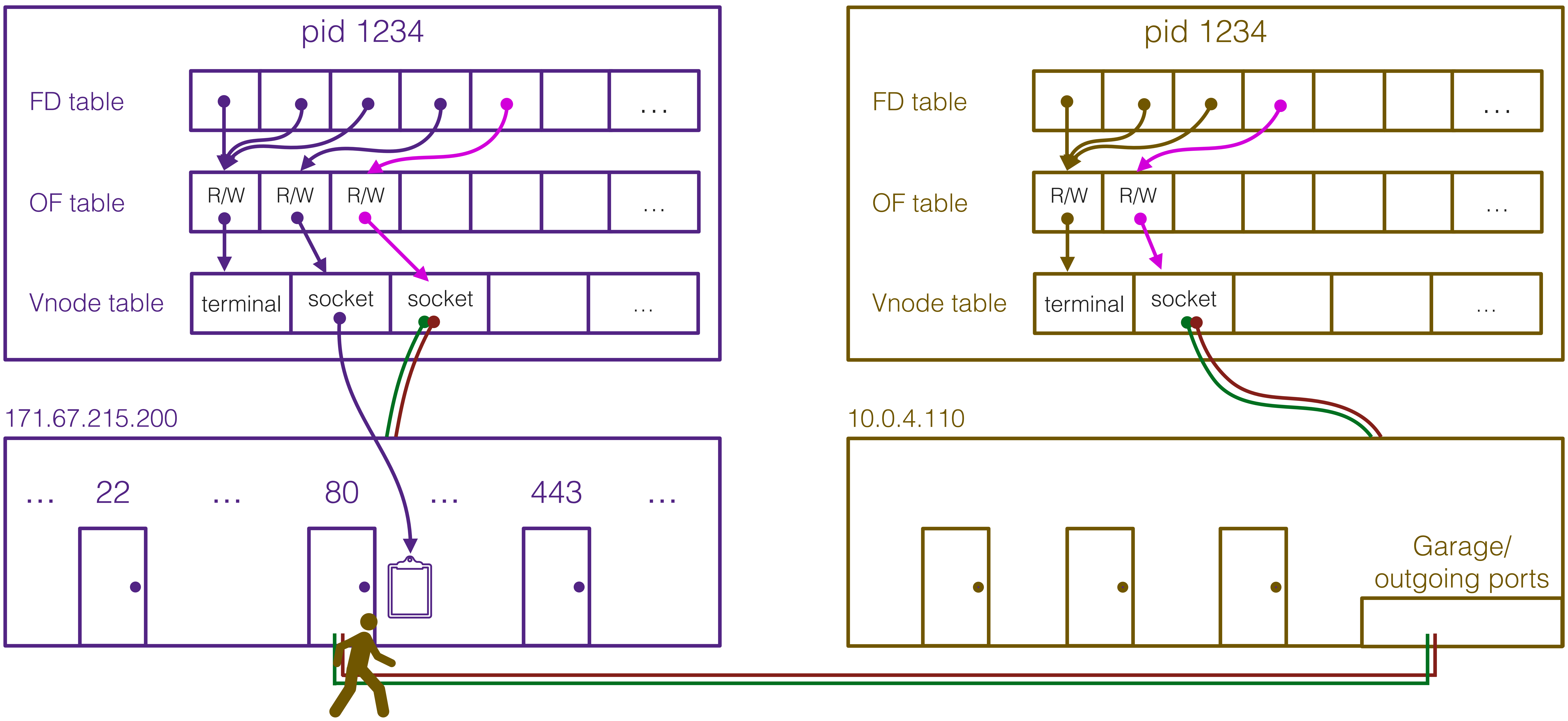
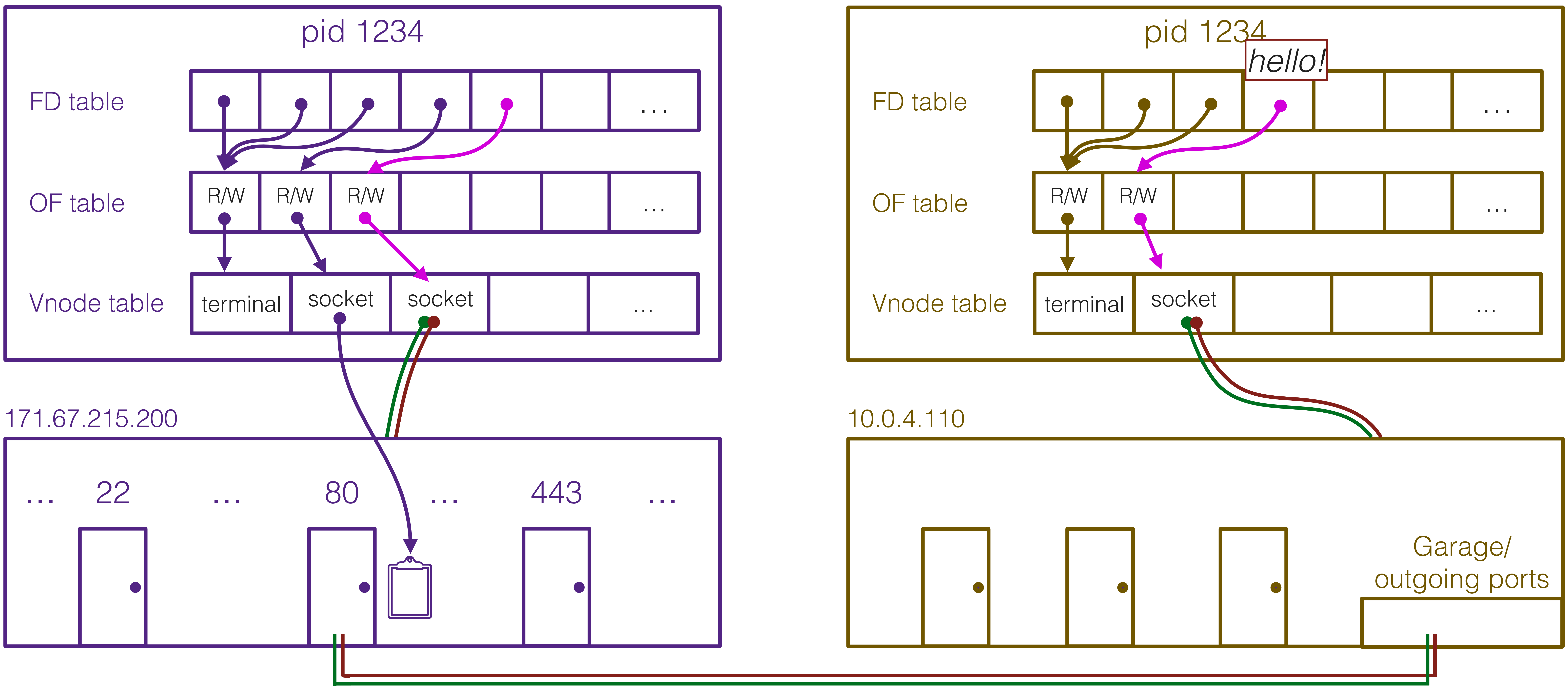




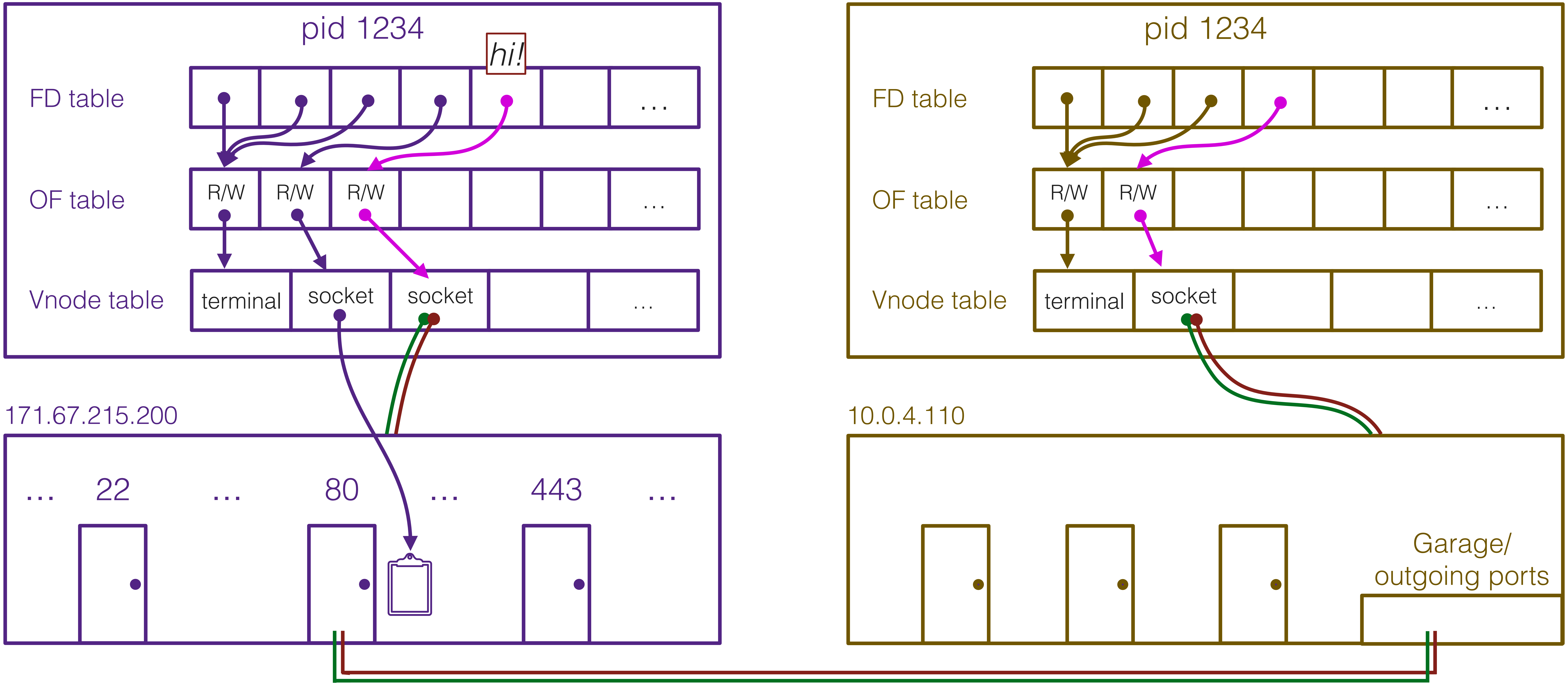
Successful in making a connection, the client also creates a new file descriptor it can use to talk to the server



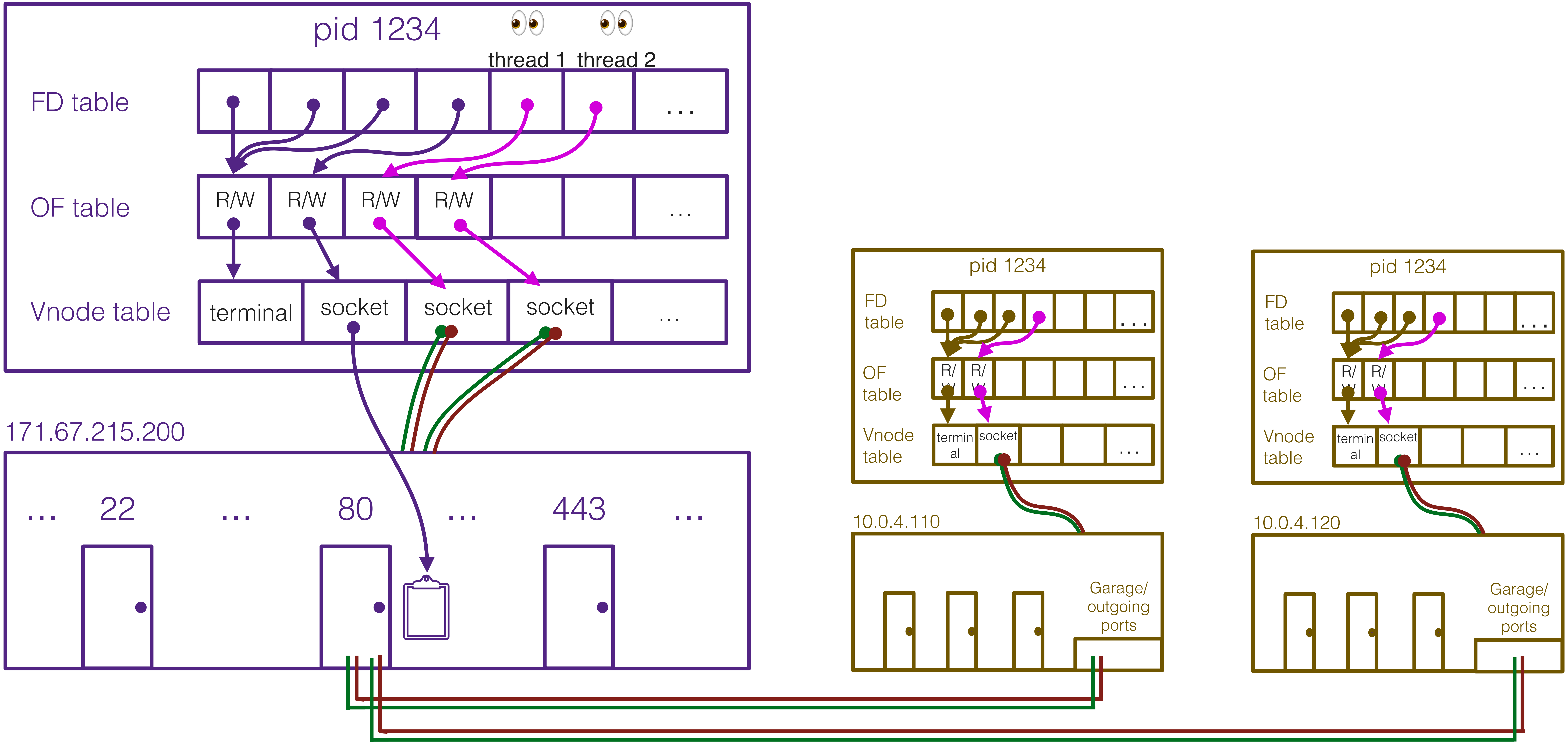
If the client writes to its fd 3, it will be readable on the server's fd 4



Similarly, if the server writes to fd 4, it will be readable on the client's fd 3



The server can talk to multiple clients at the same time, using separate file descriptors (often using a thread facilitate each conversation over each fd)

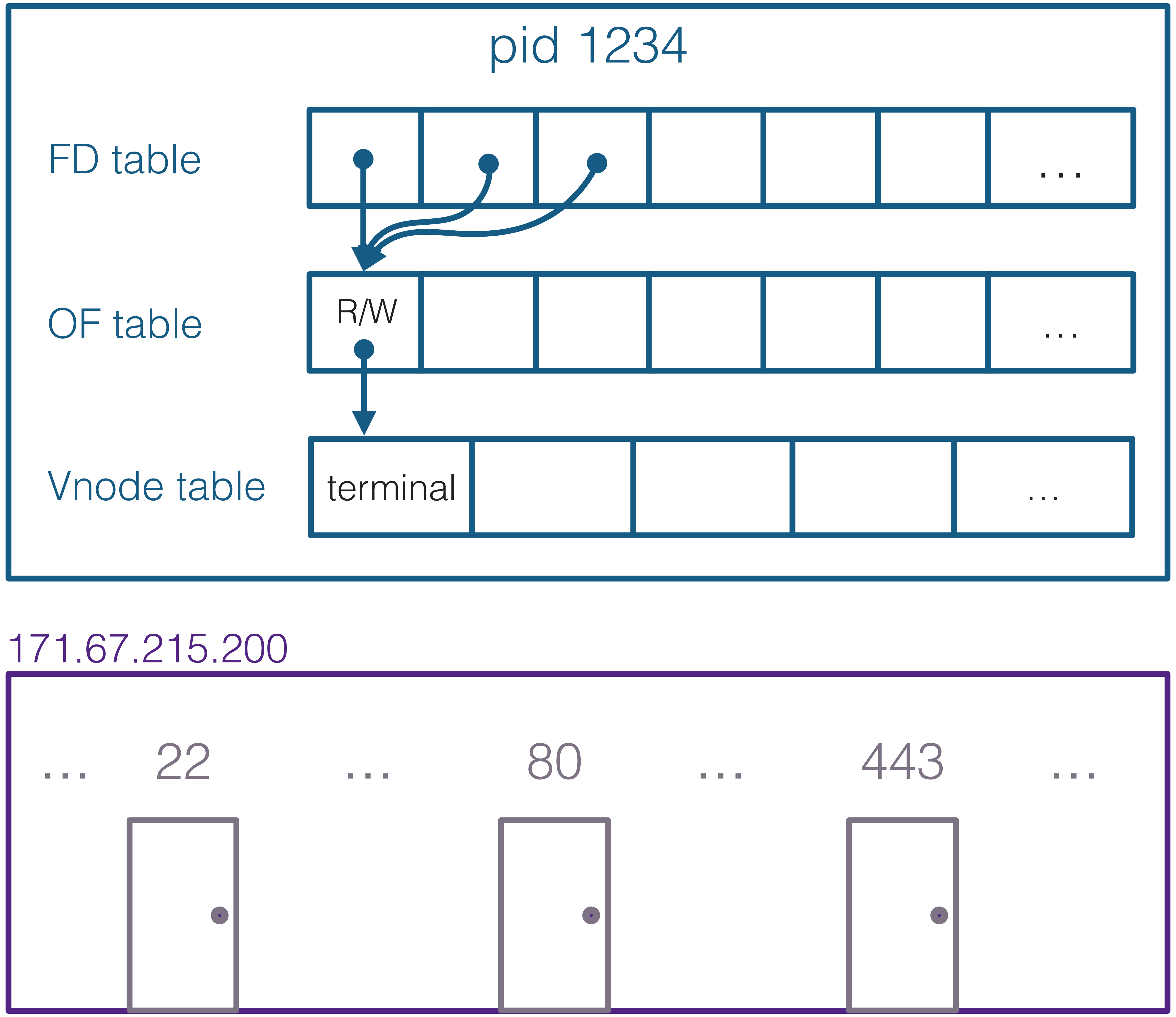


Networking syscalls

💡 You don’t need to know these super well, but you should have some sense of what is happening behind the scenes.

```
int fd = socket(AF_INET, SOCK_STREAM, 0);
```

Allocates a socket that will use IPv4 and TCP (TCP provides a reliable pipe-like stream of communication — more next Wednesday).
The socket isn't attached to anything yet.



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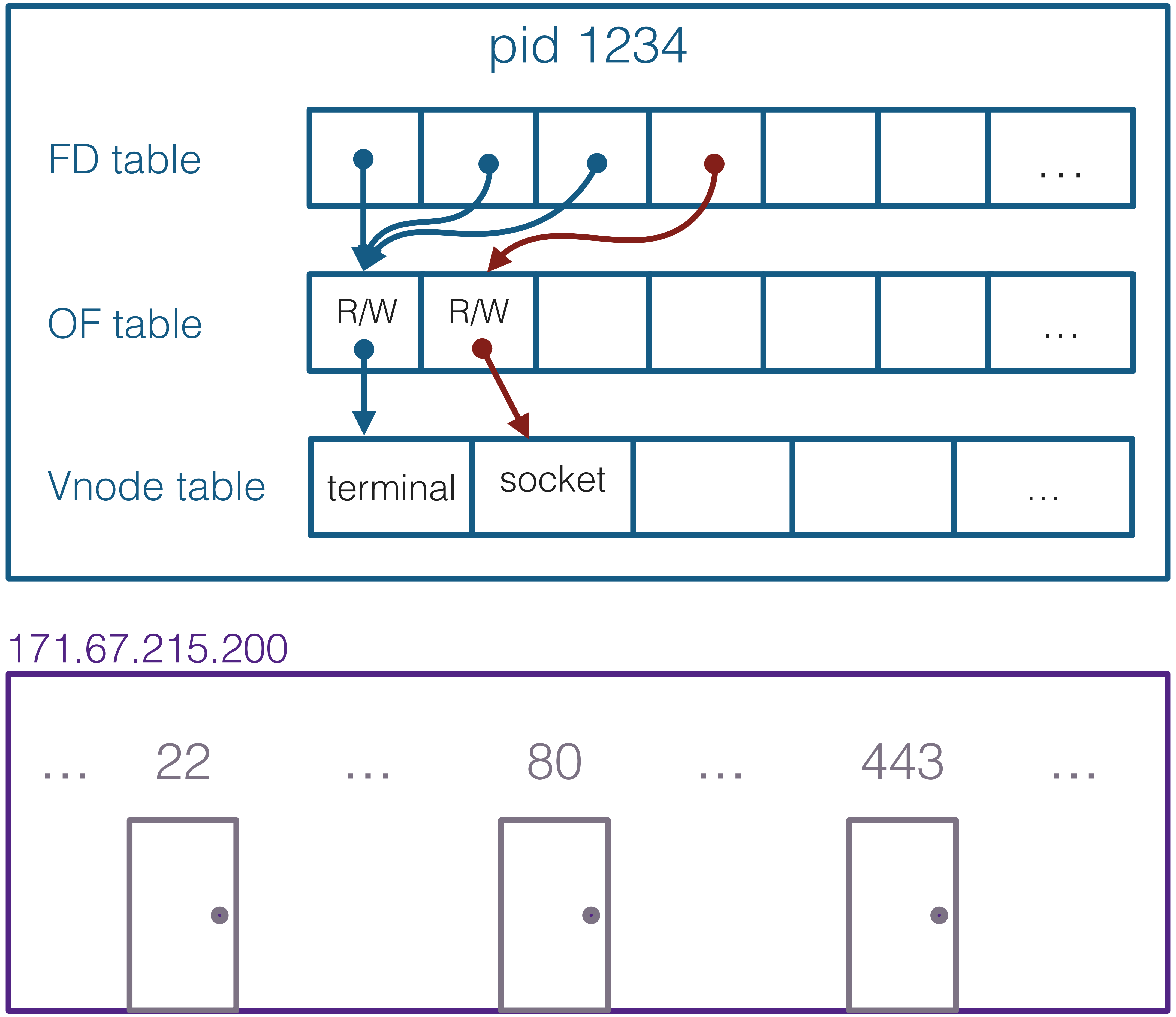
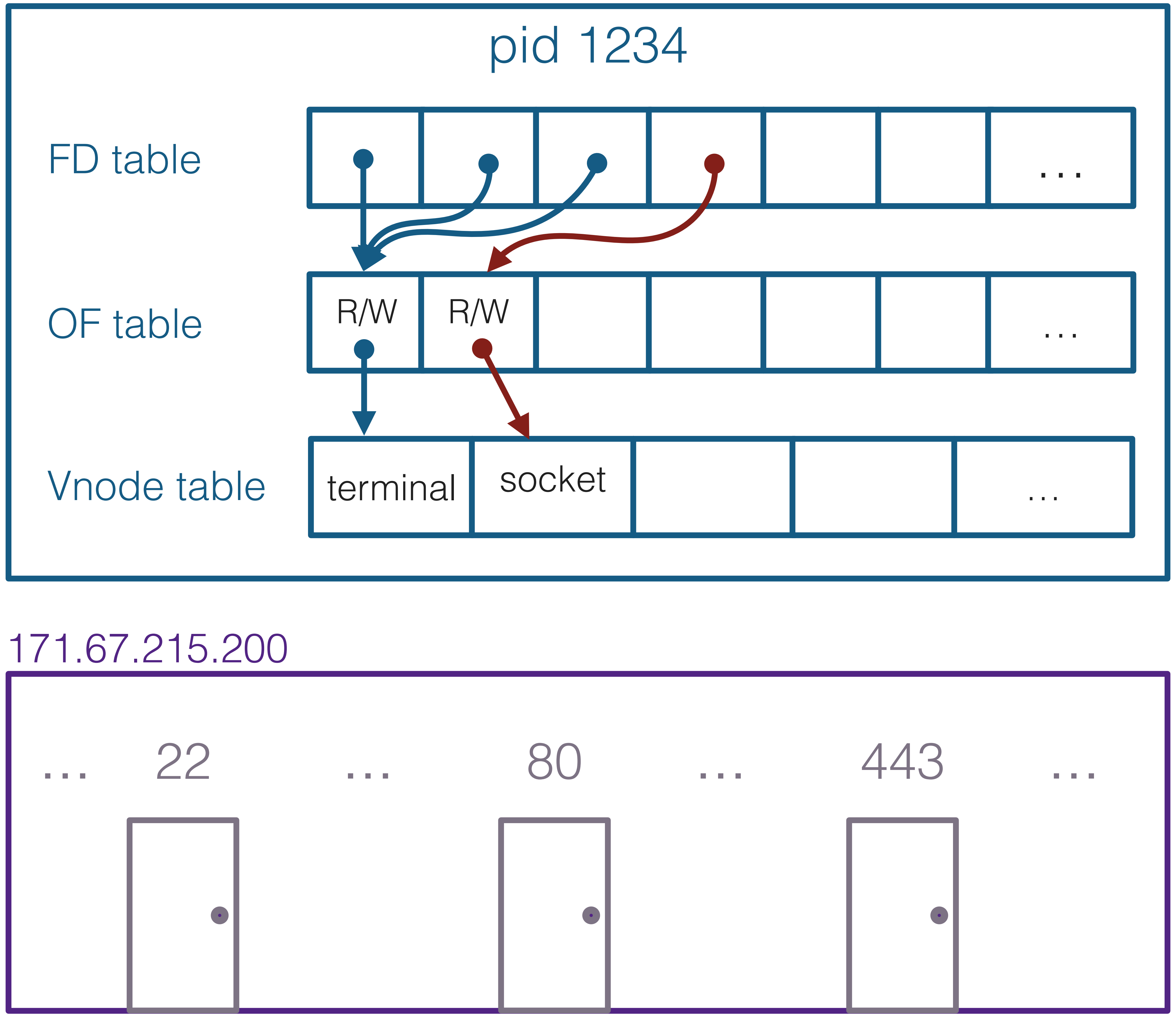


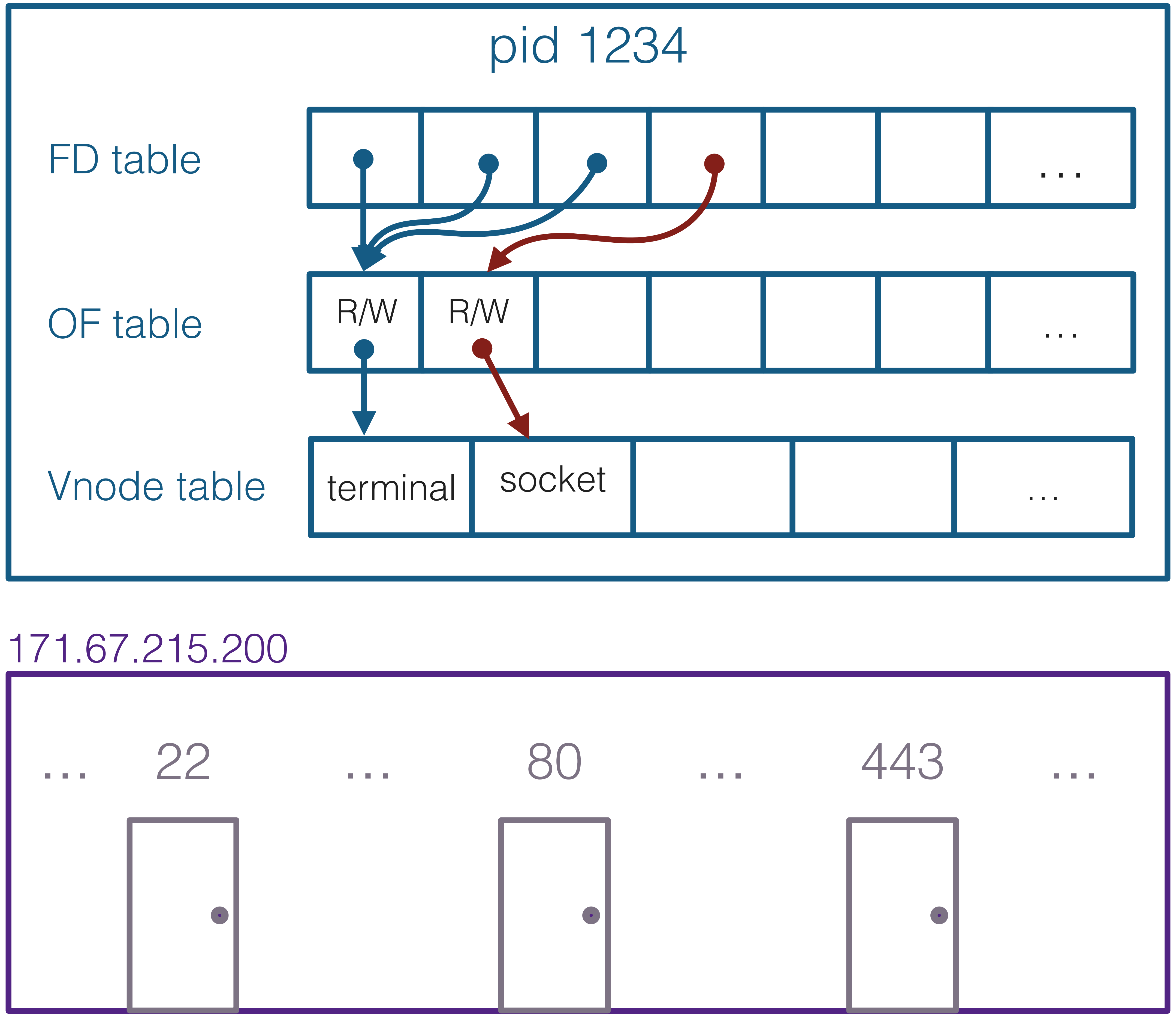
```
struct sockaddr_in address;
memset(&address, 0, sizeof(address));
address.sin_family = AF_INET;
address.sin_addr.s_addr = htonl(INADDR_ANY);
address.sin_port = htons(port);
```

Initialize a `struct sockaddr_in` with the IP address and port that we wish to listen on



`bind(fd, (struct sockaddr *)&address, sizeof(address))`

“Move into the apartment”: Tell the OS that we would like to use the specified IP/port. If that port is already in use, `bind` will return -1.



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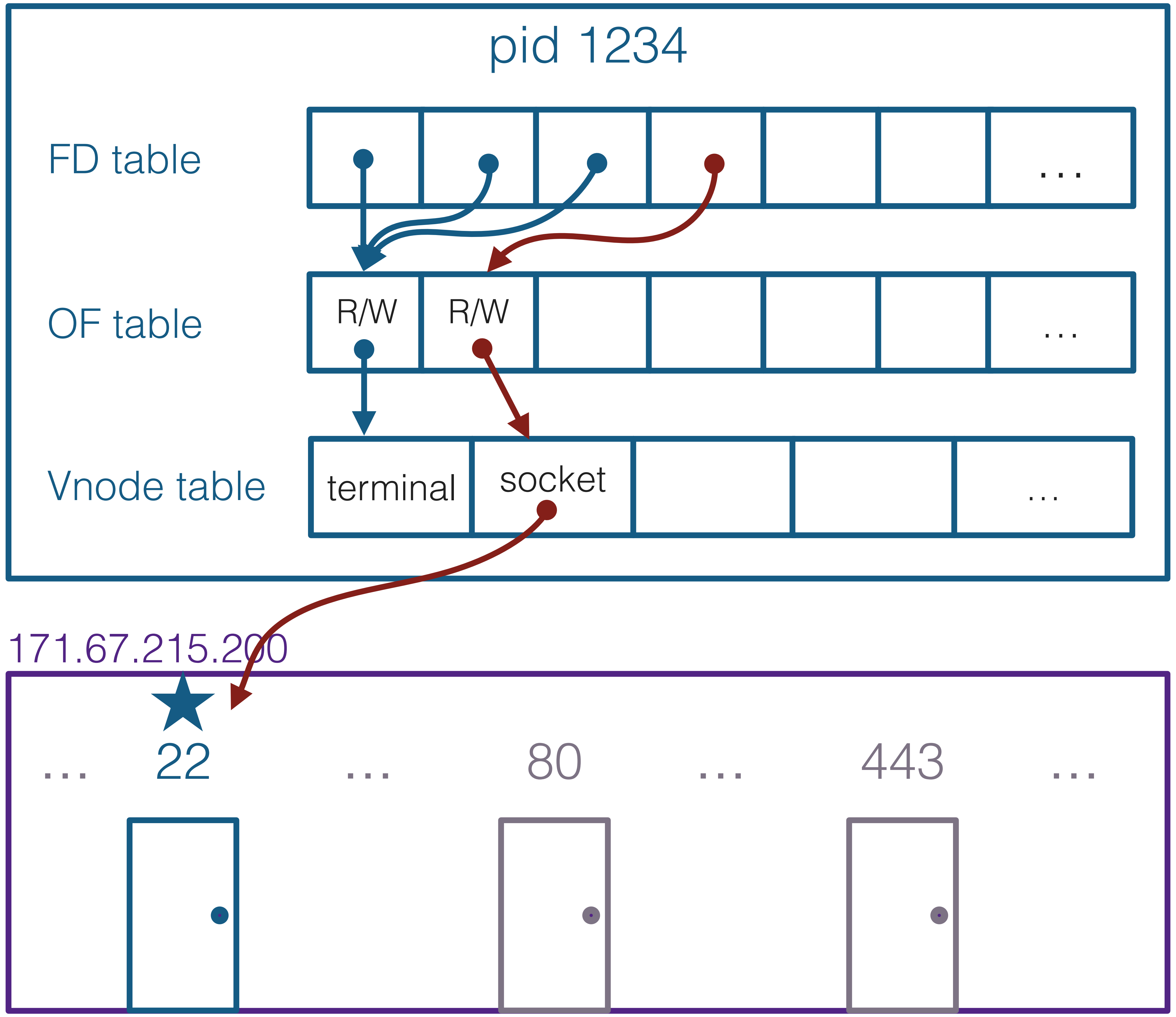
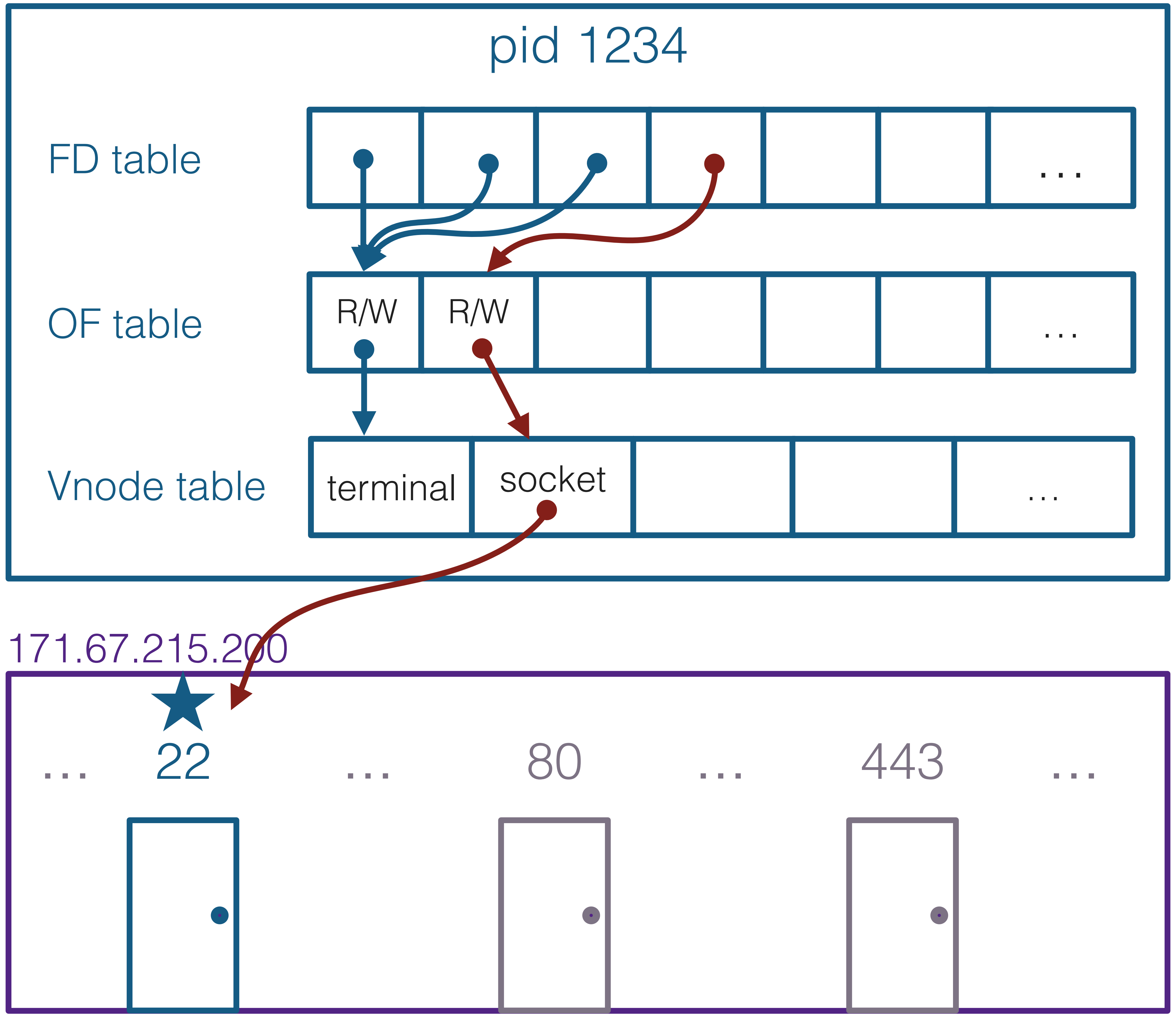


`listen(fd, 128)`

Install a waiting list with room for 128 waiting clients, and start listening for connections (when someone shows up, they will be added to the waiting list)



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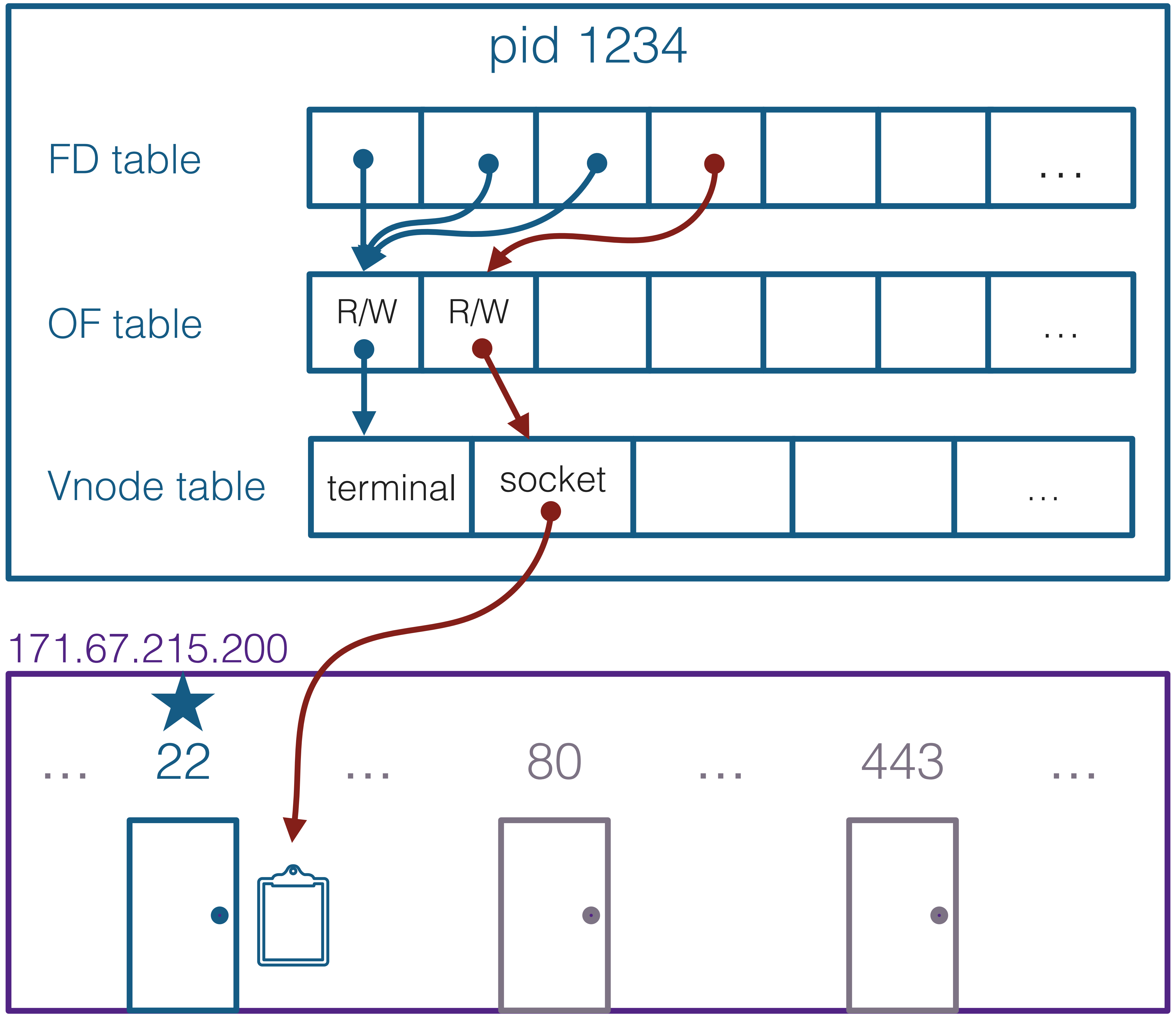
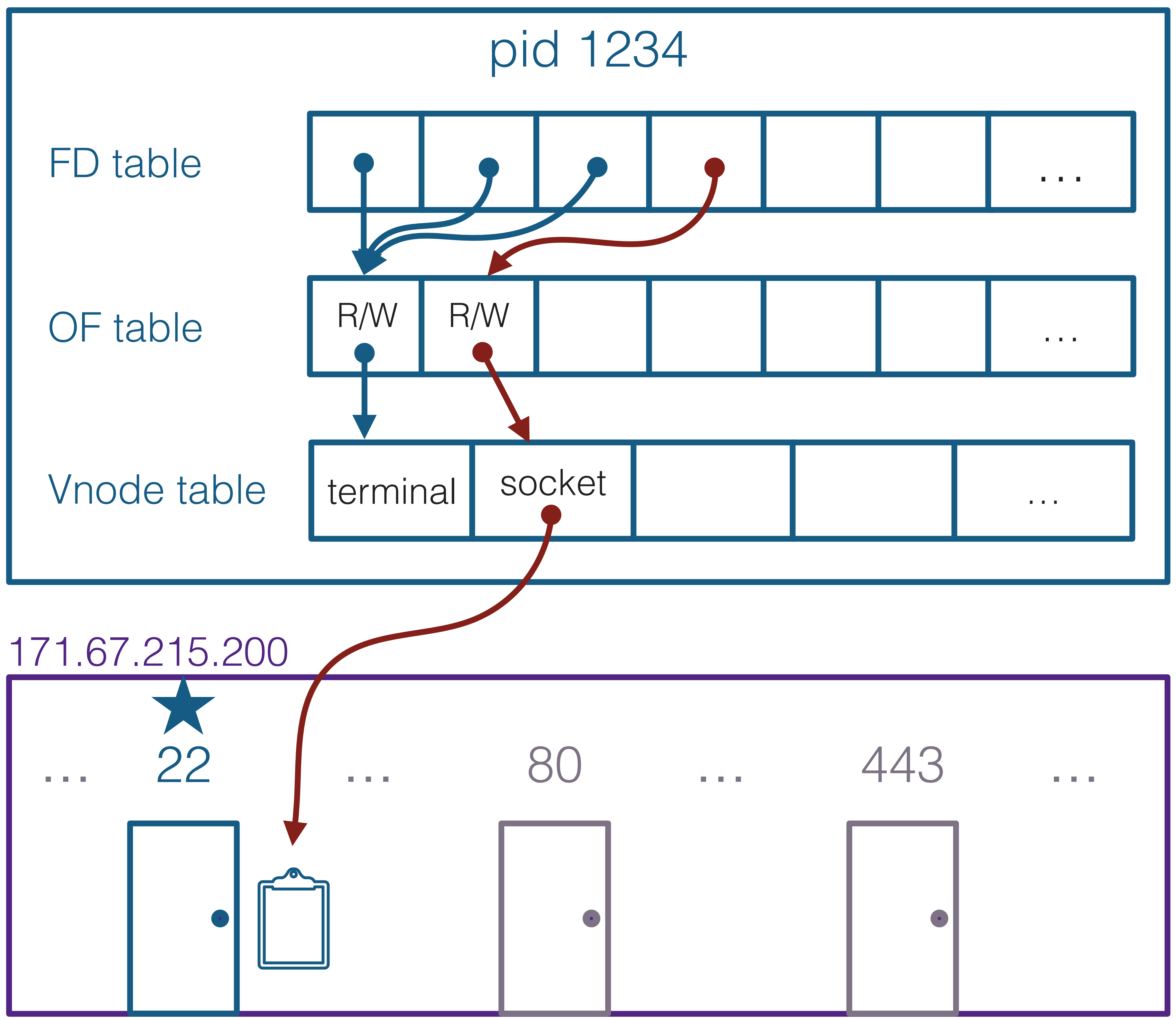
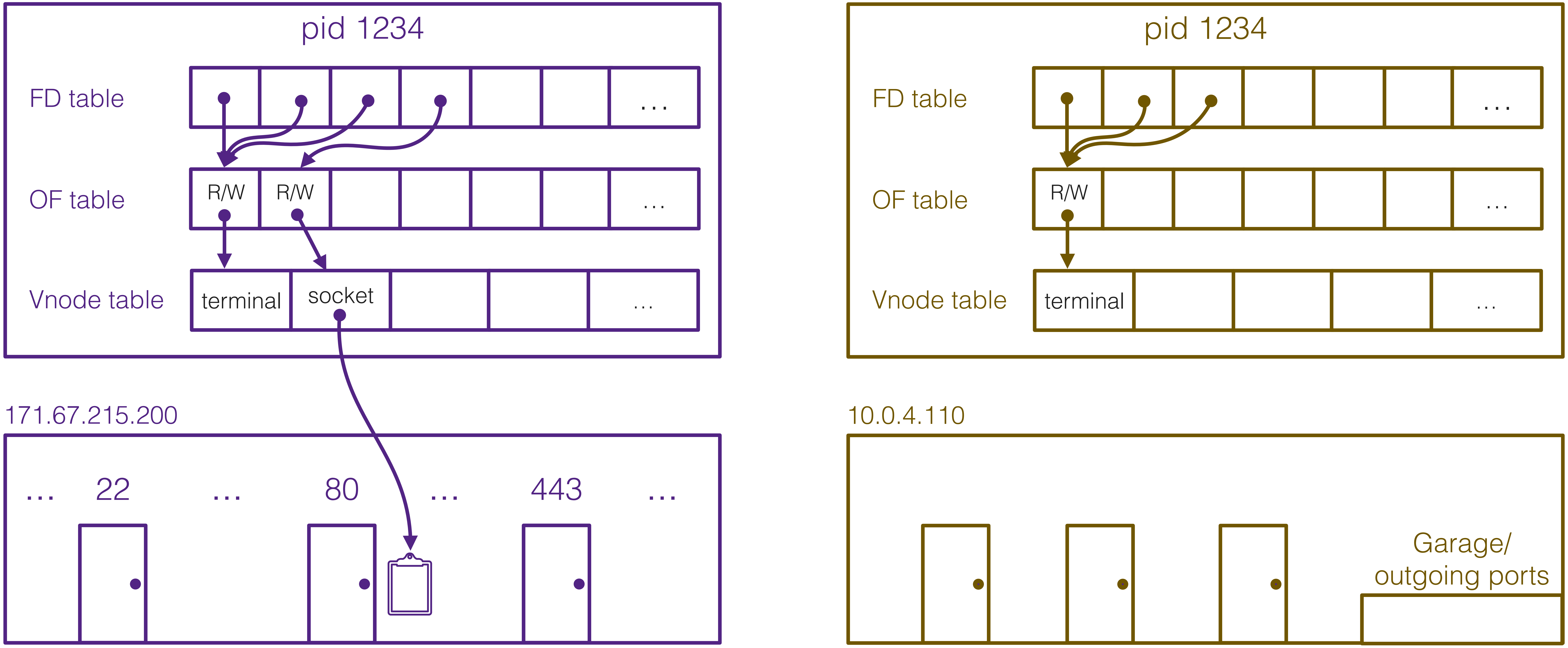


`int fdConnectedToClient = accept(fd)`

Watch the waiting list, waiting for someone to connect. (`accept` blocks until then.)

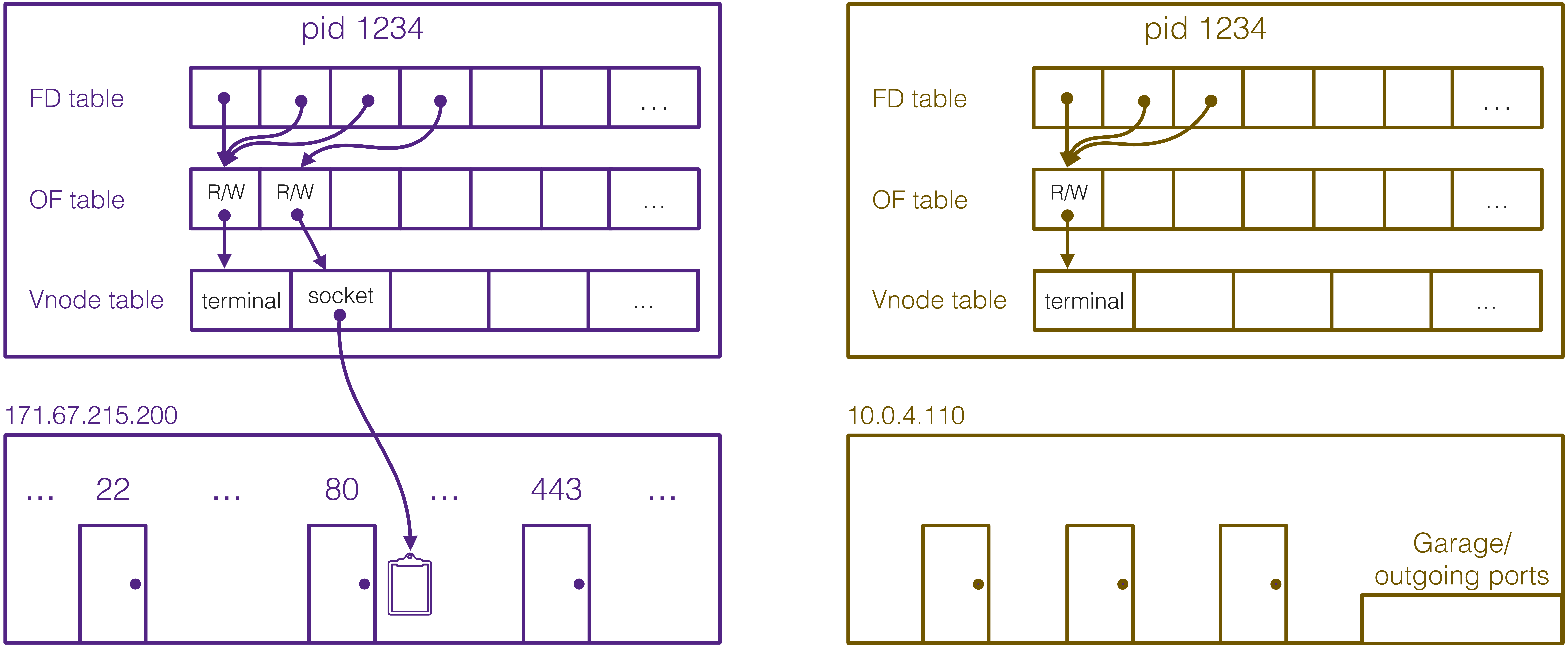


On some other computer, we want to talk to web.stanford.edu (the server)



First, we need to do a DNS lookup to figure out its IP address:

```
struct hostent *he = gethostbyname("web.stanford.edu");
```



We allocate a socket to use for this connection:

```
int fd = socket(AF_INET, SOCK_STREAM, 0);
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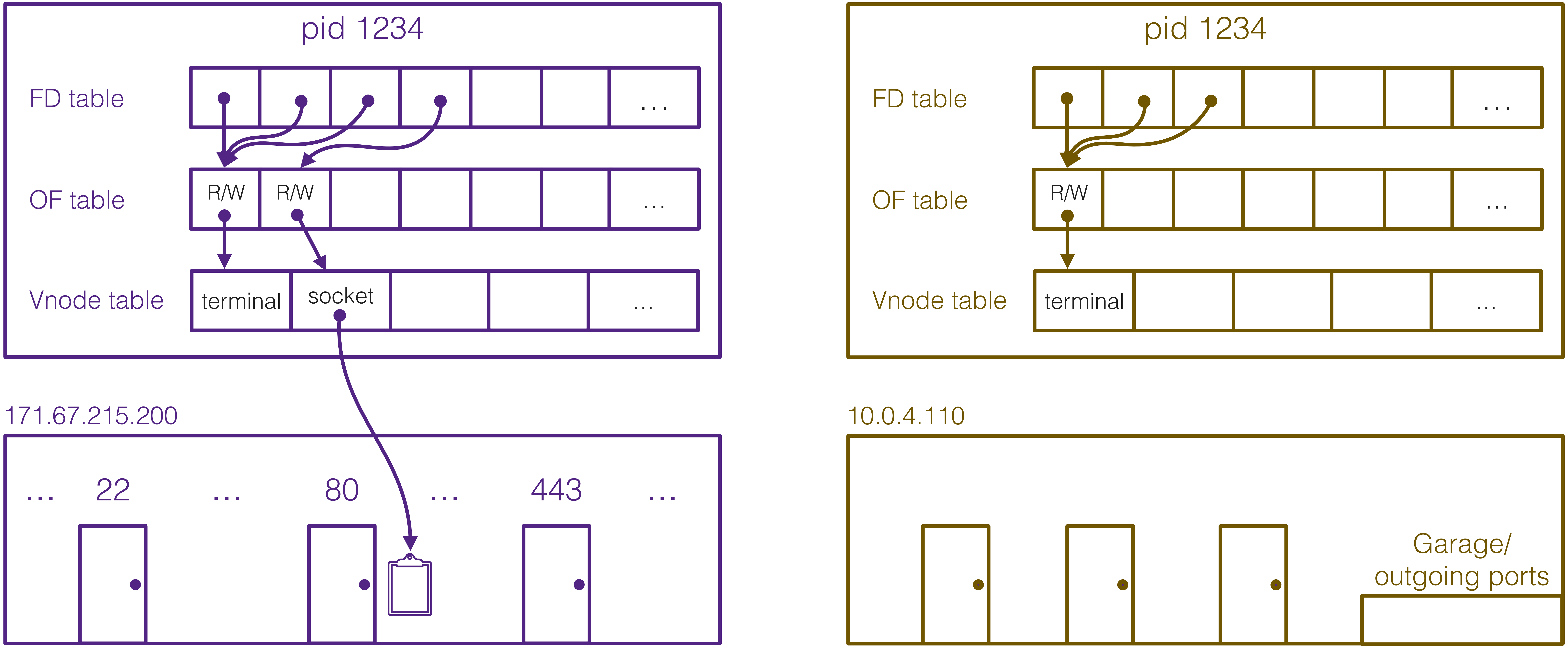

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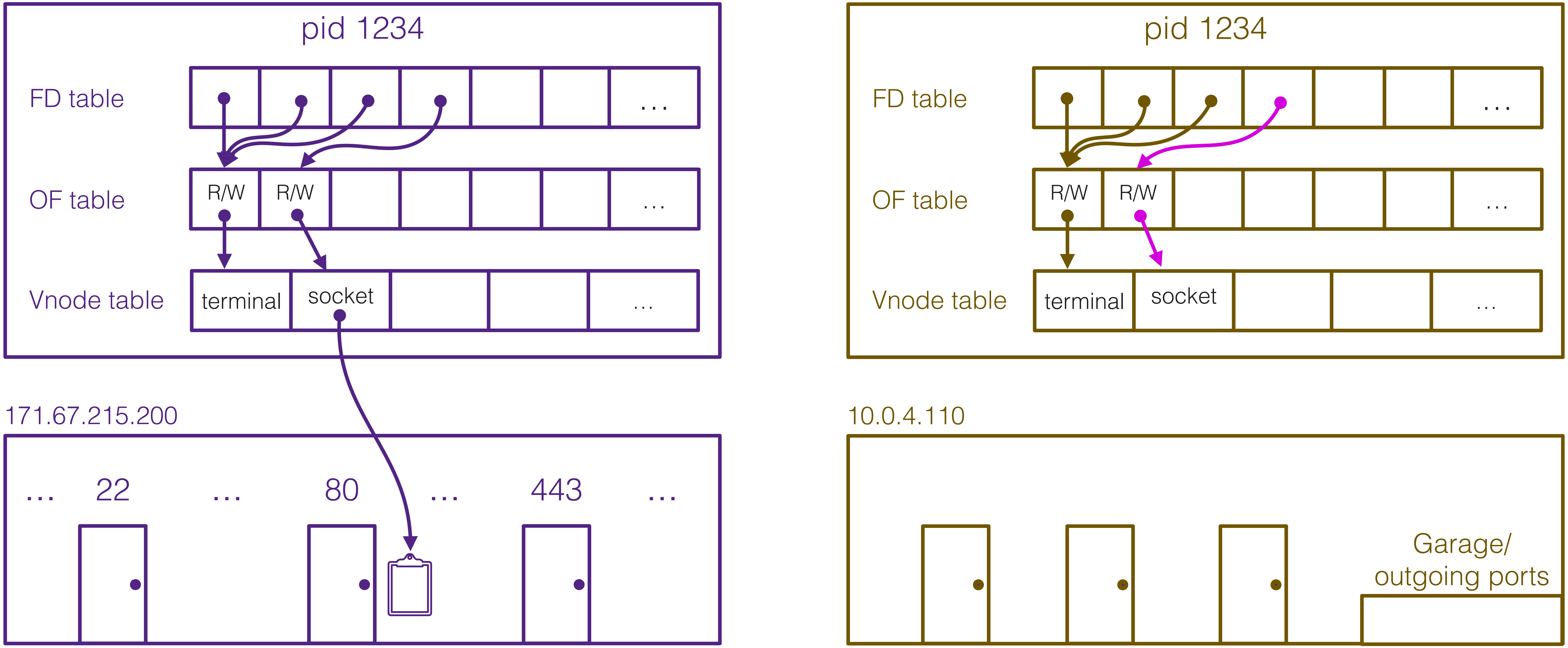
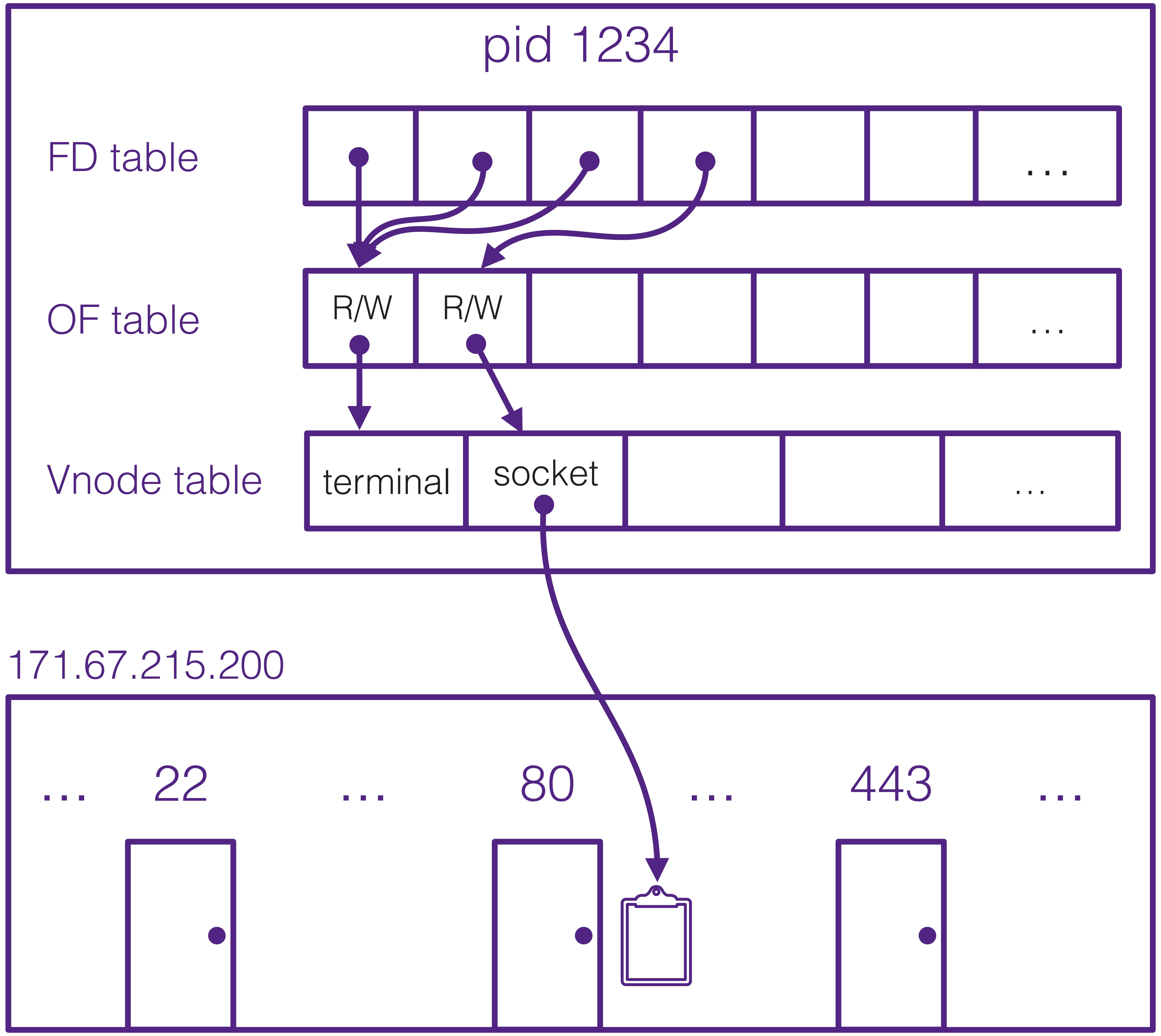
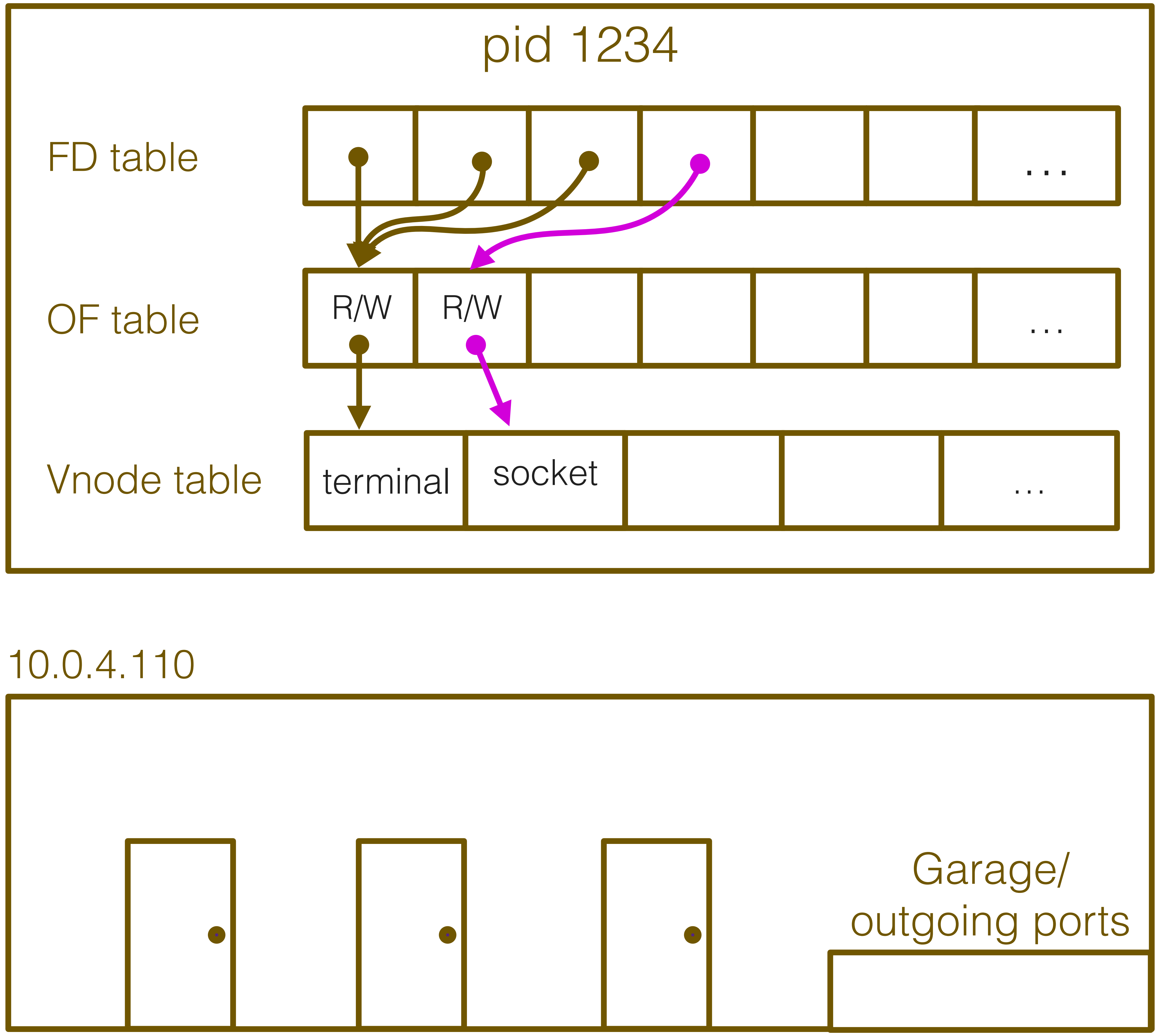


We construct a struct sockaddr_in to specify which host/port we wish to connect to:

```
struct sockaddr_in address;
memset(&address, 0, sizeof(address));
address.sin_family = AF_INET;
address.sin_port = htons(80);
address.sin_addr = *((struct in_addr *)he->h_addr);
```





Finally, we tell the OS to use our socket to connect to the specified host/port:

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connect(fd, (struct sockaddr *) &address, sizeof(address))
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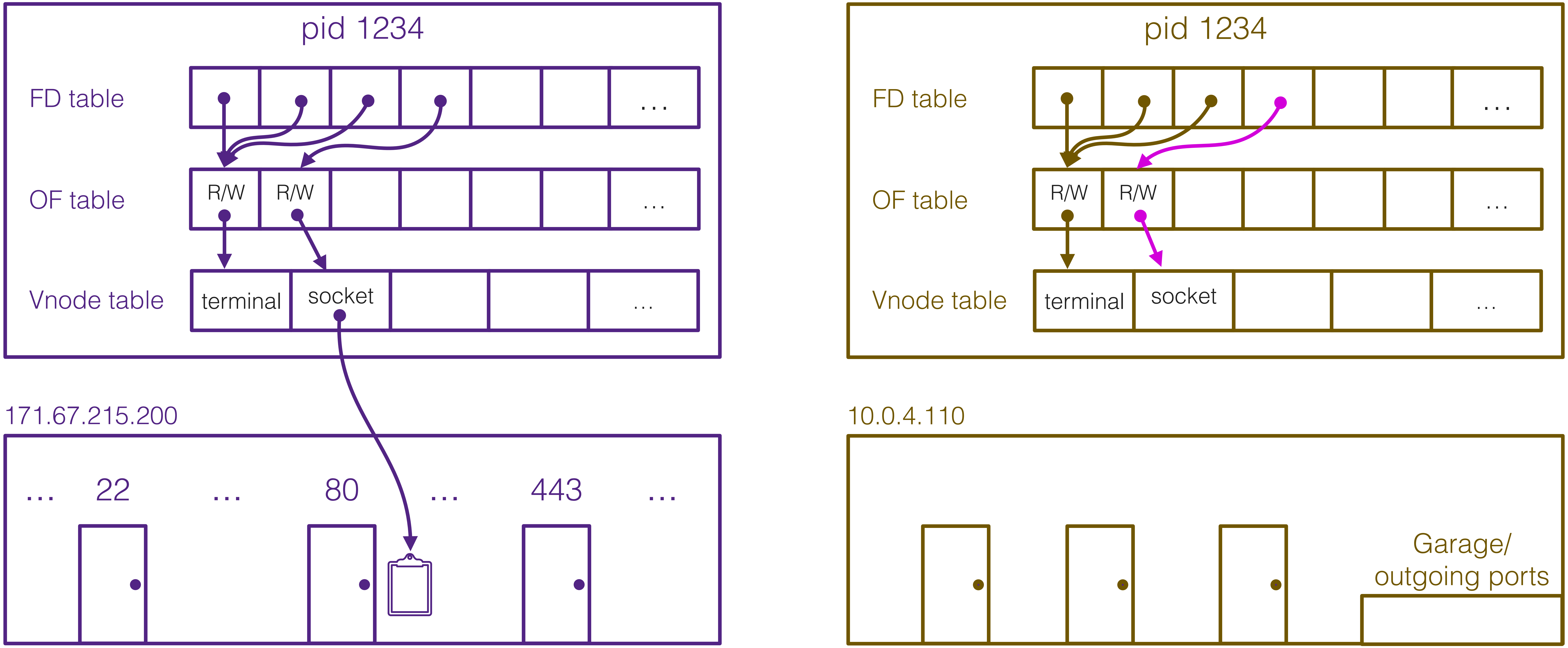

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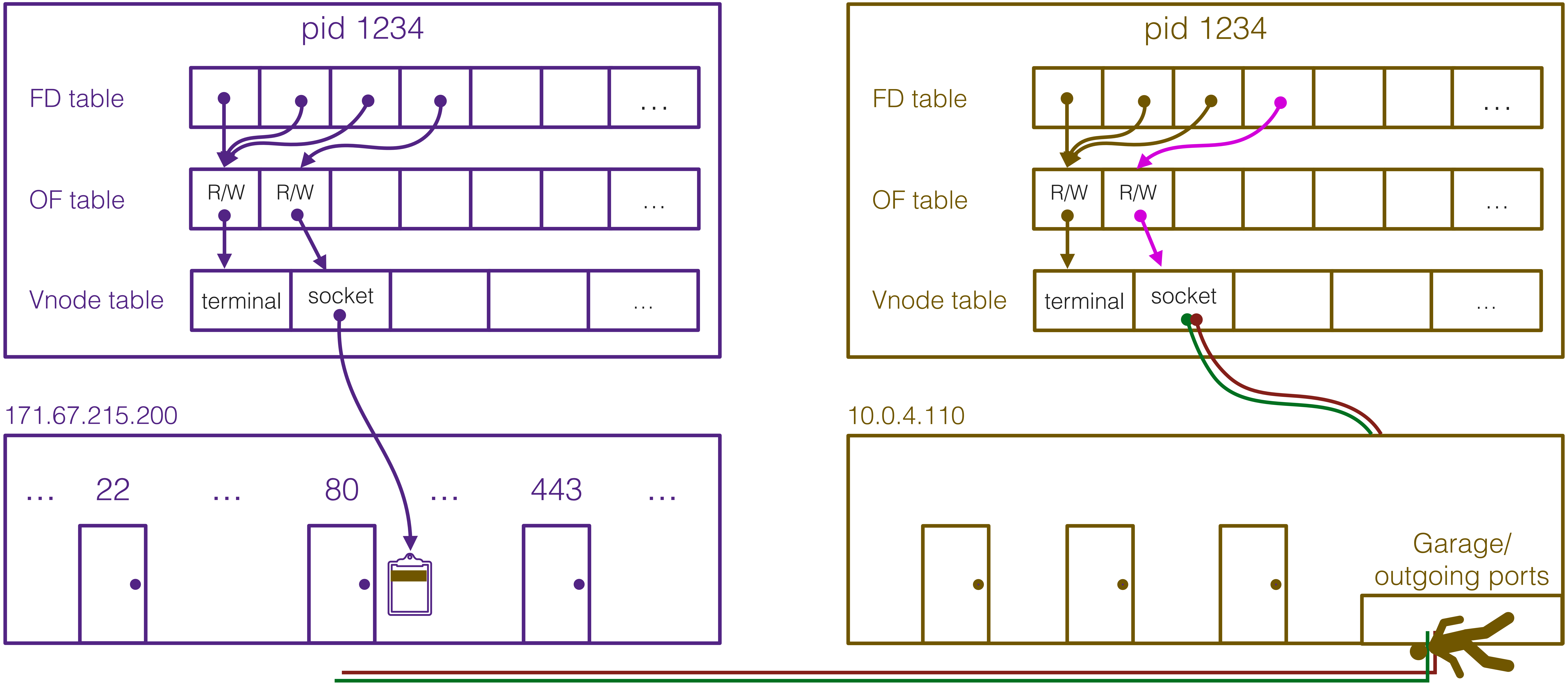

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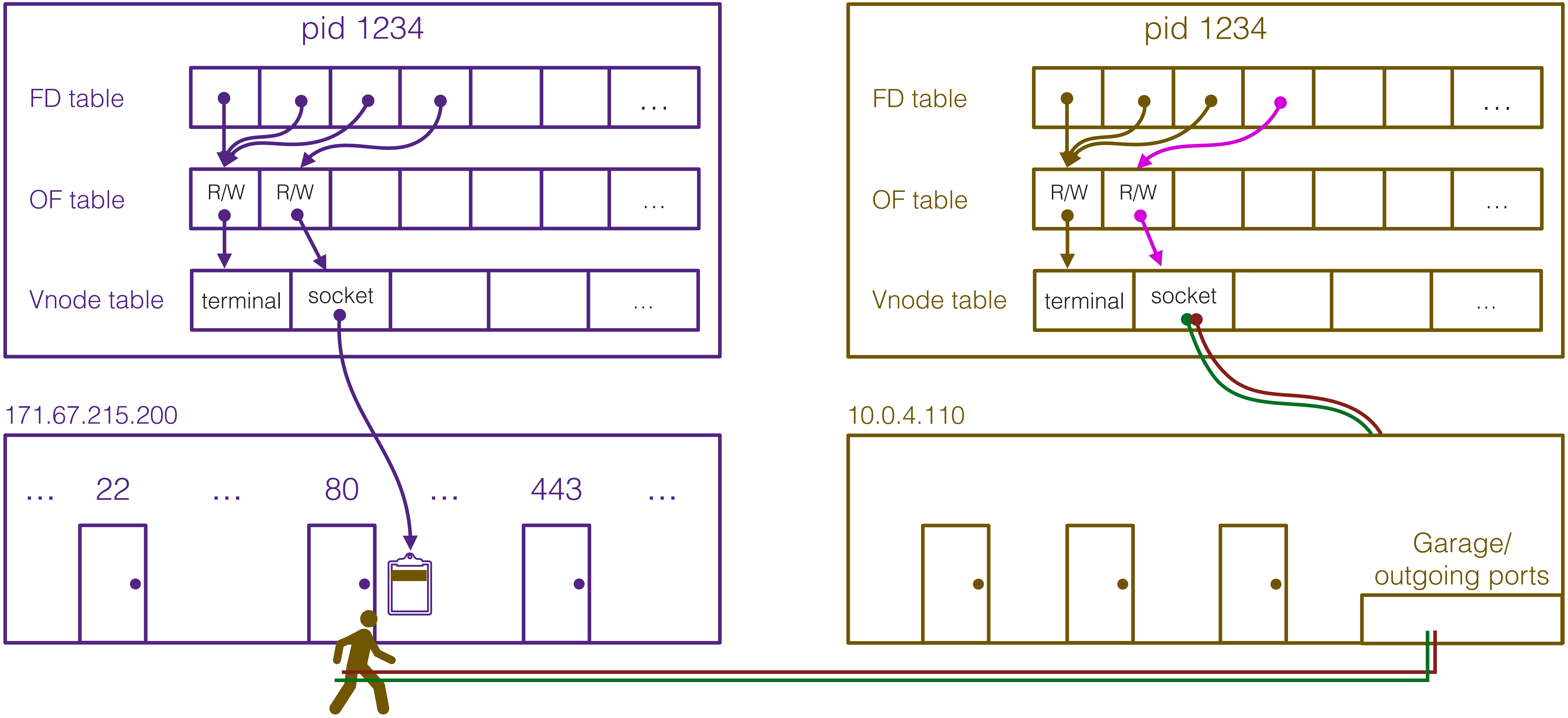

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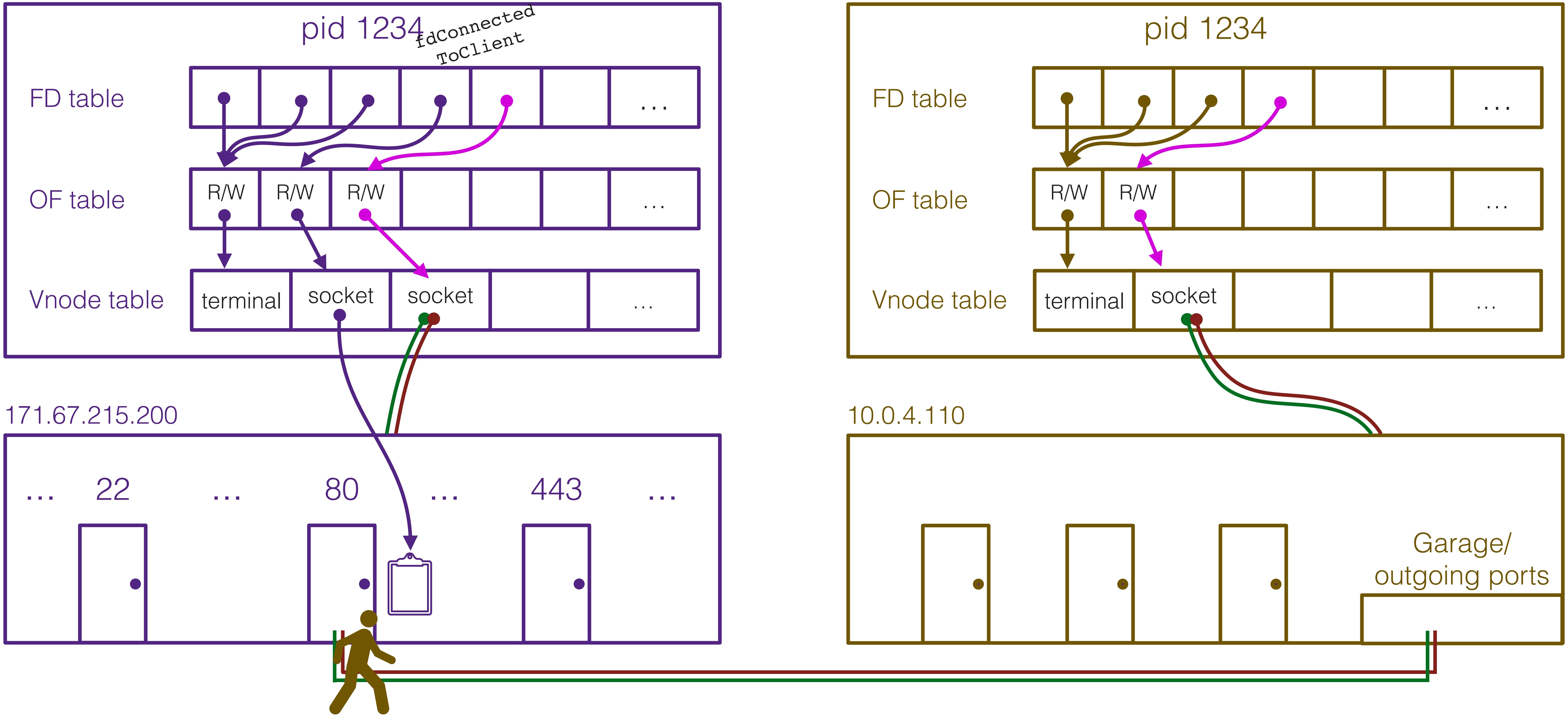

What can you do with this?

What can you do with this?

- Multiprocessing: you don't need to implement *everything* within your program. You can use other executables on the machine
- Networking: you don't even need to have everything working on one machine. You can use other machines to help you out
    - Google Images: search images of cats within a fraction of a second. It wouldn't be possible to store all the images that Google Images has on a single machine
    - Distributed computation: e.g. rendering an animated film using a large server farm

What can you do with this?

- Look up words in a dictionary:
  `echo "define * networking" | nc dict.org 2628`
- Print to your networked printer(!!!):
  `echo "Hello world" | nc 10.0.4.175 9100`

Networking APIs

- API: structured way of asking for something and getting a response (more next Monday)
- http://icanhazip.com: tells you your IP address
- http://api.open-notify.org/astros.json: list astronauts currently in space
- https://www.placecage.com/200/400: generate a placeholder image of the given dimensions featuring Nick Cage
- https://placekitten.com/: same as above, but with kittens
- Other lists:
  - https://apilist.fun/
  - https://www.reddit.com/r/webdev/comments/3wrswc/what_are_some_fun_apis_to_play_with/