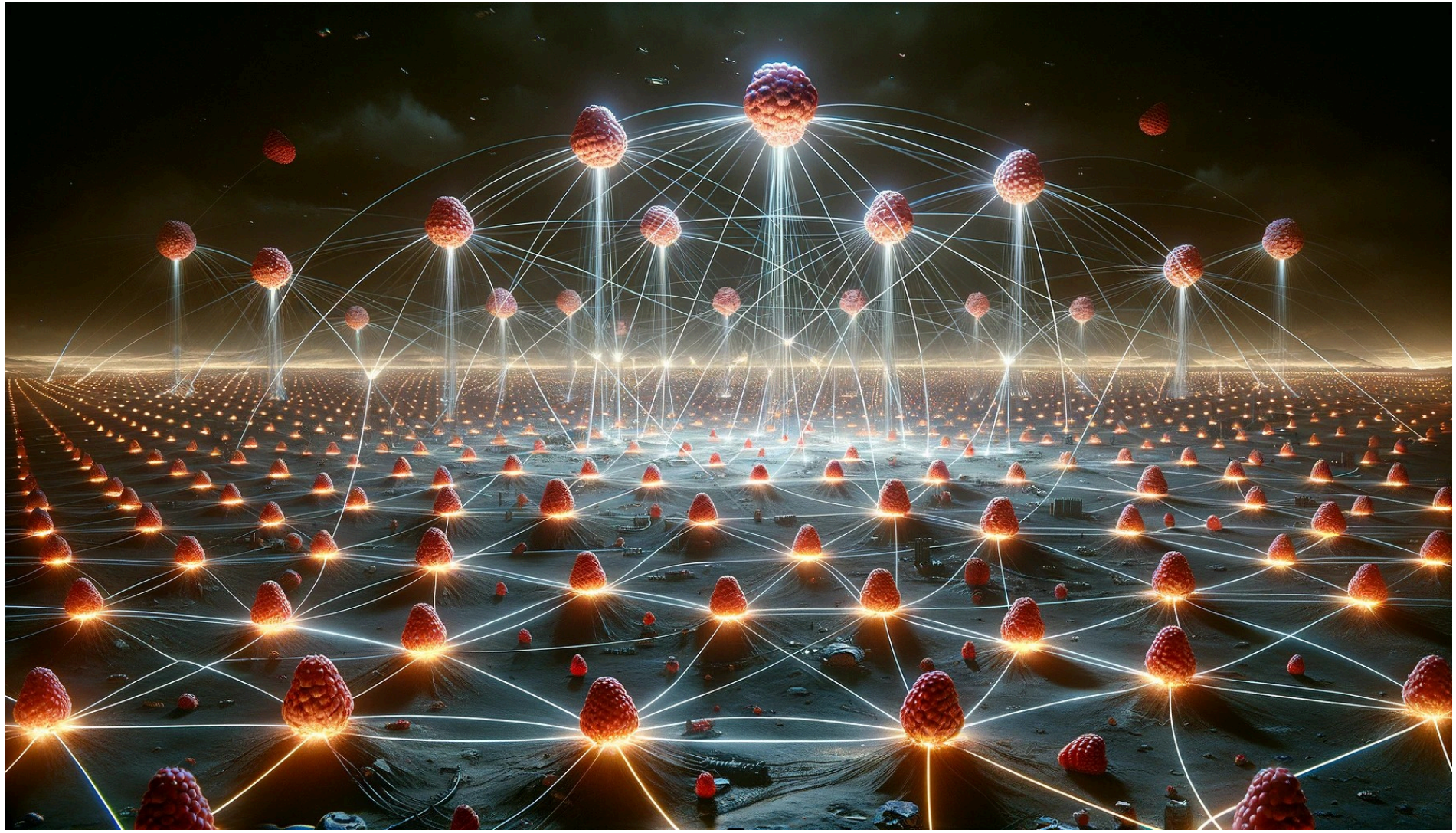
Lab 14: NRF (140e:win26)

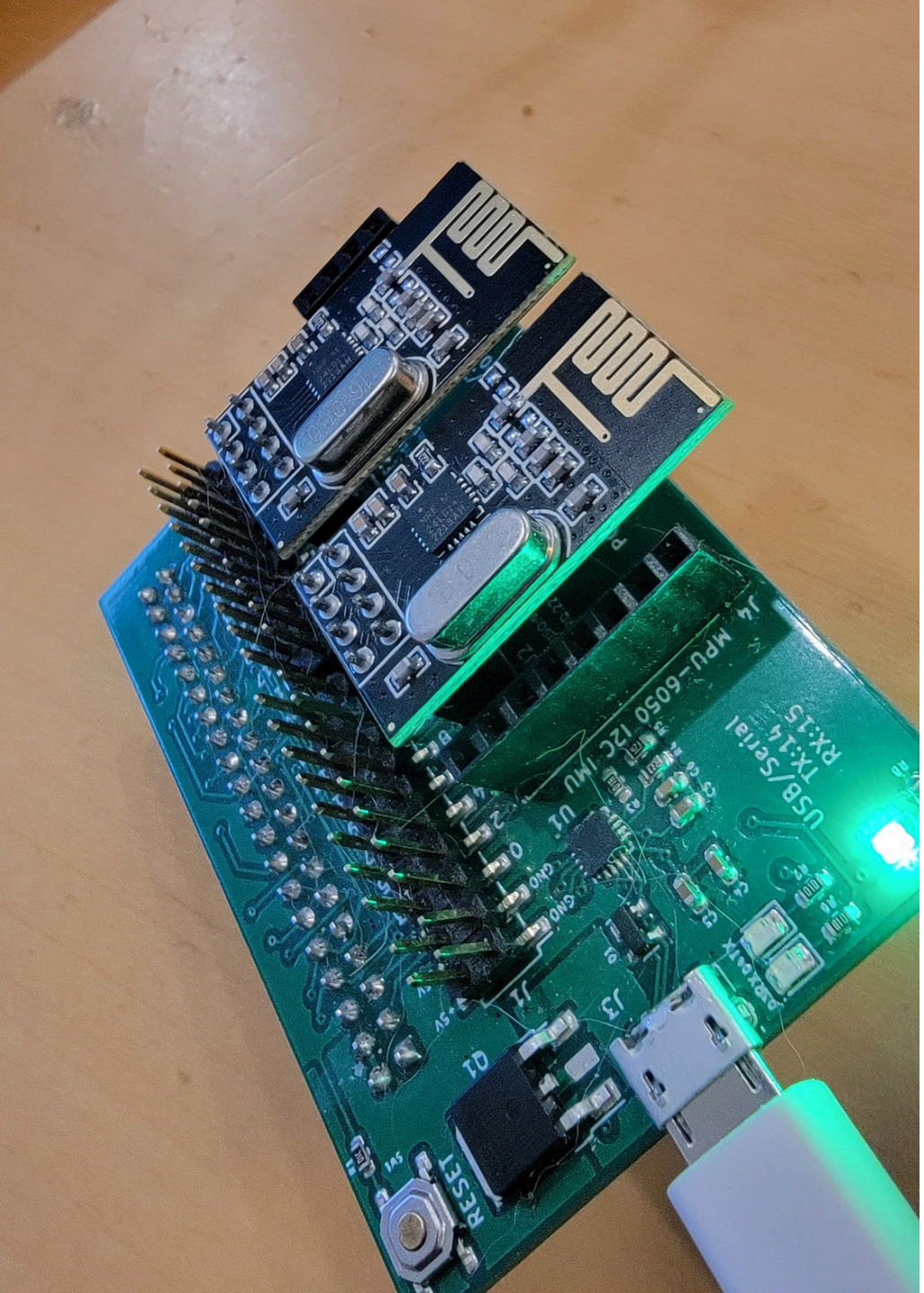


today: use two NRFs to send + receive to yourself.

- Various high bits:
  - 1-32 byte packets with CRC + dest address
  - NRF hardware can do timeout+ack retransmission
    - but if need reliable: you still have to do as well.
  - up to 2mb/s, with standard RF tradeoff:
    - faster = shorter range, but less chance for collision.
  - *2^7* different channels (+ can dynamic hop)
  - Seperate device, doesn't see power cycle on reboot.
- Huge gotcha:

i. TX and RX are seperate modes.

ii. Cannot RX packet if in TX mode.



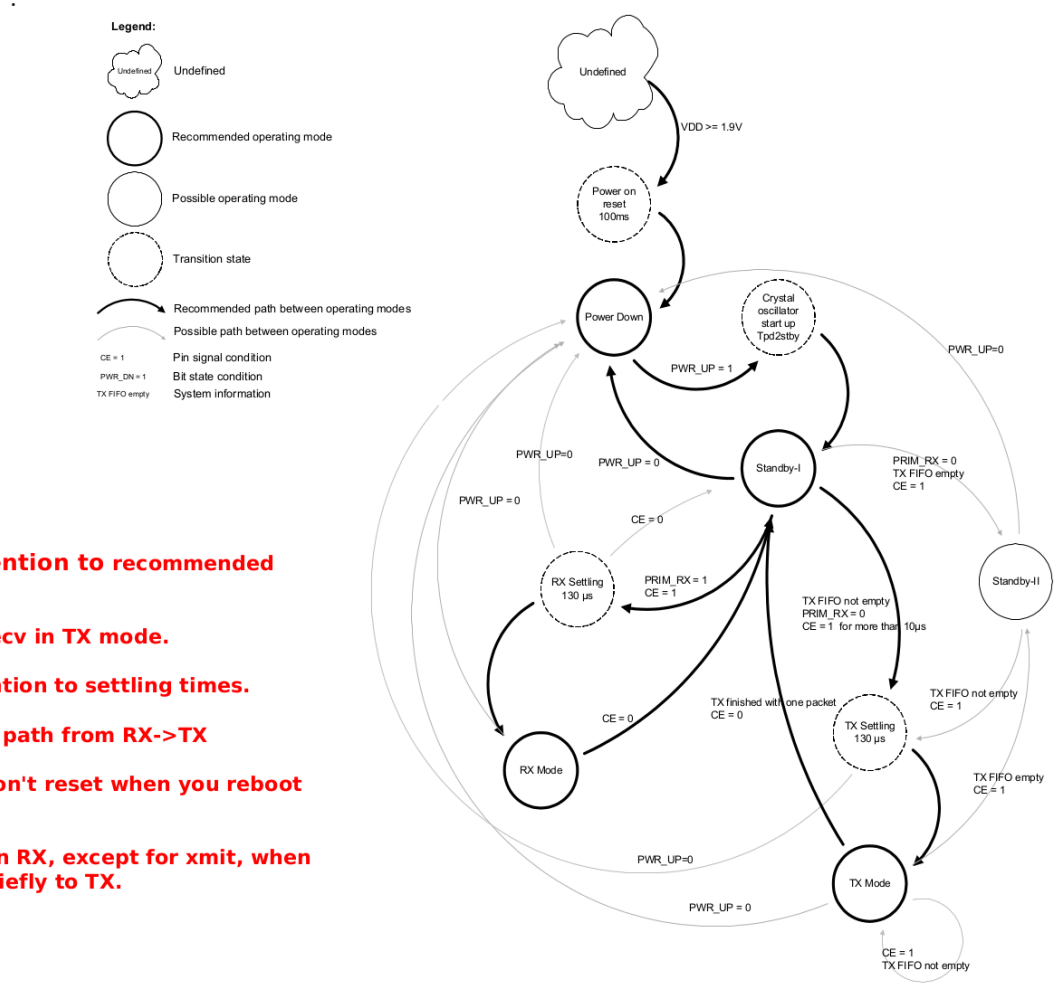
Big ups to Parthiv board!

- Today is a big reason we use Parthiv
  - Pi talks to NRF using SPI
  - SPI faster than I2C, but 4 wires vs 2.
  - total wires: 4 SPI + 3v + gnd + CE
    - 7 wires x 2 ends x 2 NRF = 28 endpoints
    - Pr(misconnect|loose) ~ 1
- No Parthiv-board?
  - Then can't do lab w/ 93 students.
  - (240lx: he teaches a pcb lab.)

Big datasheet = big starter code (sorry)

- What you modify:
  - `nrf-driver.c`.
- What you have:
  - `nrf.h`: defines datastructure and configuration.
  - `nrf-hw-support.h`: many accessors for NRF registers.
  - `nrf-hw-support.c`: SPI routines, and `nrf_dump` (you'll use this alot)
  - `nrf-public.c`: wrapper over the low level nrf driver.
  - `nrf-test.h`: helpers for testing.
- Great extension is to rewrite! or do in daniel mode.

The state machine (fixed-pt: stay in RX)



pay attention to recommended states.

cannot recv in TX mode.

pay attention to settling times.

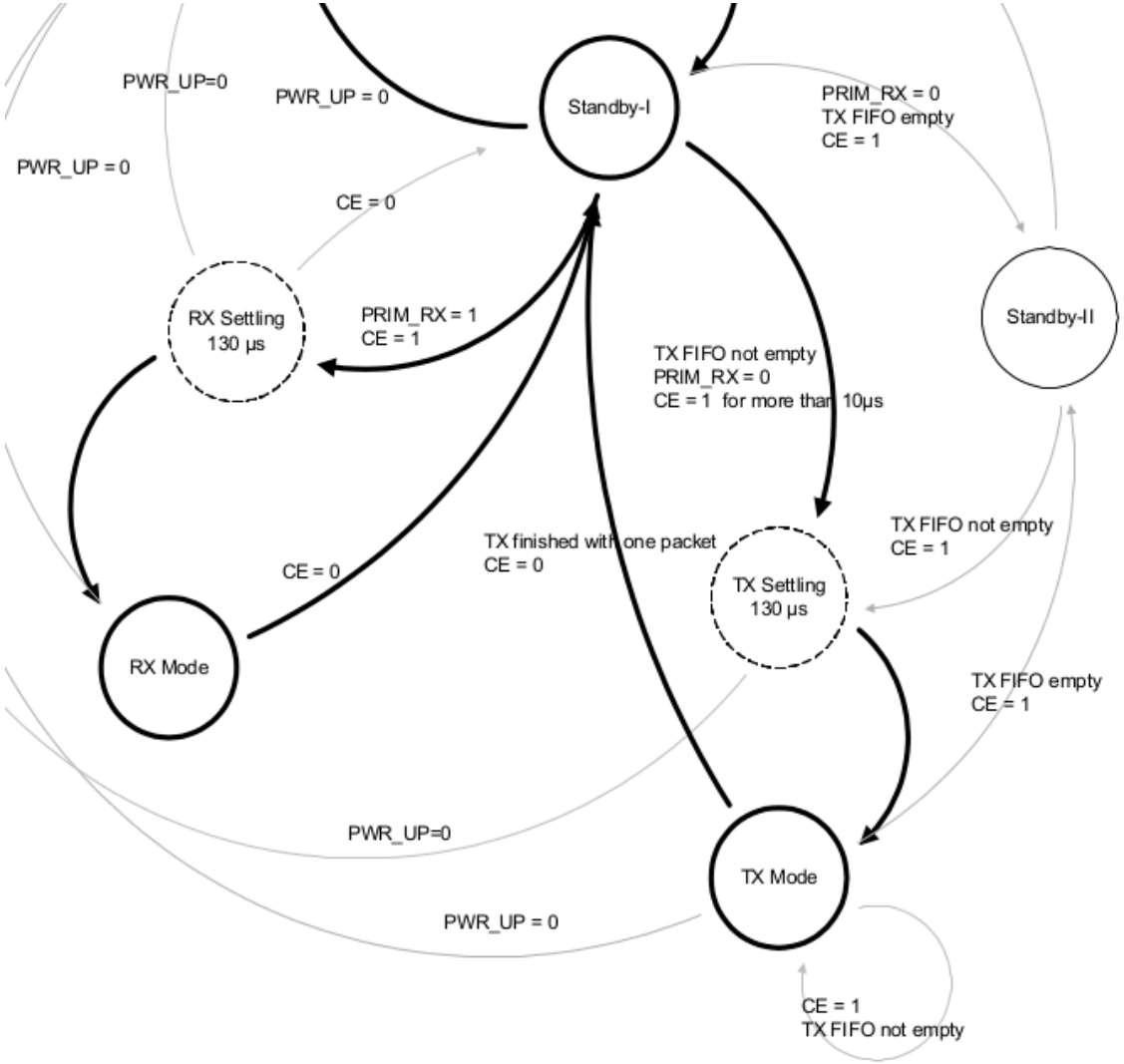
no direct path from RX->TX

device won't reset when you reboot the pi.

we stay in RX, except for xmit, when switch briefly to TX.

Figure 4. Radio control state diagram

To transmit: do RX->Standby-I->TX



How to SPI

- Same metaphor as GPIO: read and write "registers"
  - but instead of load/store to address
  - use SPI to read/write 8-bit registers with 1+ bytes
    - more honest: explicit i/o.
  - Read back what you wrote: Catches many errors.
  - We own device: don't RMW during init

```
// nrf-hw-support.h: has many others.
// read 8 bits of data from <reg>
uint8_t nrf_get8(const nrf_t *n, uint8_t reg);
// write 8 bits of data to <reg>: returns <CONFIG>
uint8_t nrf_put8(nrf_t *nic, uint8_t reg, uint8_t v);
// write 8-bit <v> to <reg> and then check get8(reg) = <v>.
uint8_t nrf_put8_chk(nrf_t *nic, uint8_t reg, uint8_t v);
```

Huge cheat code: read-back any value you set

- As with any device: if you set a deterministic register: read it back.
- Catches many human errors trivially:
  - register discards values in ways you didn't expect.
  - register uses a different size than expected
  - you misunderstood the helper routines
  - Device mis-configuration:
    - e.g., SPI clock was too fast so the device couldn't keep up.
- Catches many broken hardwares trivially:
  - if one of your NRF devices (or Parthiv board slots) is dead.

Common symptom: `MAX_RT`

- Seeing a lot of `MAX_RT` (p59)?
    i. if consistent:
    - likely send/receive pipes don't match
    - e.g., different packet size or ack settings

    ii. if sporadic:
    - collisions: change the channel you're using.

Mistake: NRF addresses are > than one byte!

- You must use `nrf_get_addr` and `nrf_set_addr methods` (nrf-hw-support.c)
  - They do sanity checking
  - They use the right SPI calls to set and get multiple-bytes.
- Just setting addresses with a 8-bit SPI cmd = truncate + not work.

Mistake: Hard-coding a value in `nrf_init`.

- Hard-coding value = very hard to debug
  - Will work fine on initial tests (we don't randomize).
  - Then won't work when you use different value
    - For example changing RX or TX addresses
- Each year this mistake causes groups to waste hour+.

Mistake: not setting CE

- If:
  - you finished `nrf_init`
  - your `nrf_dump` matches the staff
- But:
  - you can't TX/RX/ACK anything
- Then:
  - Make sure you're setting the CE pin correctly
  - Is a GPIO pin, so you have to control it manually.

Mistake: not waiting for settling!

- P22: During boot up: `delay_ms(100)` until in "Power down"
- P22: During Standby-I->RX: `delay_us(130)`
  - avoid forbidden state.
- P24: After setting "power up" during init: `delay_ms(5ms)`
- NOTE: Can only change config in Standby-I or Power-down

Some Rules

1. Cannot receive in TX mode.
2. NRF has own power:
    - Reboot has no power on its state!
    - Can't rely on registers having "reset values"
3. Just b/c has ACKs, doesn't mean transmit "solved"
    - Retrans can be exceeded.
4. Just b/c you see an ACK does not mean other code received.
    - it might have not pulled it off RX FIFO fast enough
5. Just b/c you see an ACK does not mean other code acted.
    - might have dropped later, or crashed, or bug.
    - For a long discussion of 4/5: the End-to-end principle

Big datasheet but mainly a few pages

- State machine figure: p22-26
- Shockwave: figure p41, TX p75, RX p76
- SPI commands: p51
- TX,RX FIFO: p56
- Registers: 57-63
- Cheatsheet: ./CHEATSHEET-nrf24l01p.md

Inf Extensions!!!

- make driver as simple as possible.
- make driver as fast as possible.
- handle multiple pipes (change `nrf_t`)
- do as many NRFs as possible (final project)
- send code

Next tuesday: hard.

- VM coherence.
  - maybe the most tricky 12 pages you'll ever read.
  - not many words.
  - but very very very subtle.
- Do 3-4 passes this weekend.
  - if you don't get several sleeps will not go well.