Bluetooth Smart:

The Good, The Bad, The Ugly... and The Fix

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Black Hat USA
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Why Bluetooth Smart?

→ Because it's appearing EVERYWHERE

Why Bluetooth Smart? (2)

- 186% YoY Growth for H1 2013[1]
- "over 7 million Bluetooth Smart ICs were estimated to have shipped for use in sports and fitness devices in the first half of 2013 alone"
- "Analysts Forecast Bluetooth Smart to Lead Market Share in Wireless Medical and Fitness Devices"[2]

[1] http://www.bluetooth.com/Pages/Press-Releases-Detail.aspx?ItemID=170
[2] http://www.bluetooth.com/Pages/Press-Releases-Detail.aspx?ItemID=165

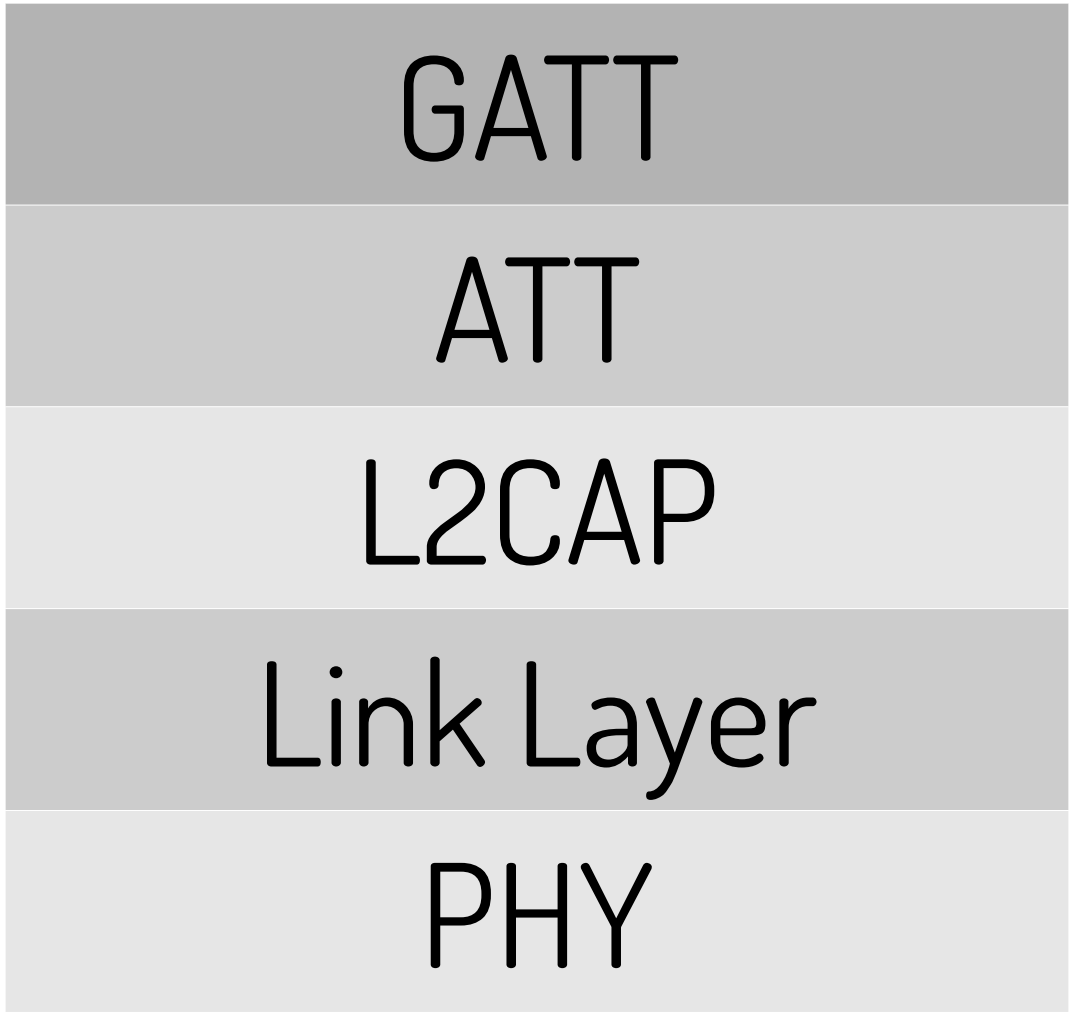
The Good

Bluetooth Smart

What is Bluetooth Smart?

- New modulation and link layer for low-power devices
- vs classic Bluetooth
  - Incompatible with classic Bluetooth devices
  - PHY and link layer almost completely different
  - High-level protocols the same (L2CAP, ATT)
- Introduced in Bluetooth 4.0 (2010)
- AKA Bluetooth Low Energy / BTLE

Protocol Stack



PHY Layer

- GFSK, +/- 250 kHz, 1 Mbit/sec
- 40 channels in 2.4 GHz
- Hopping

Hopping

- Hop along 37 data channels
- One data packet per channel
- Next channel = (channel + hop increment) mod 37

3 → 10 → 17 → 24 → 31 → 1 → 8 → 15 → ...

hop increment = 7

Link Layer

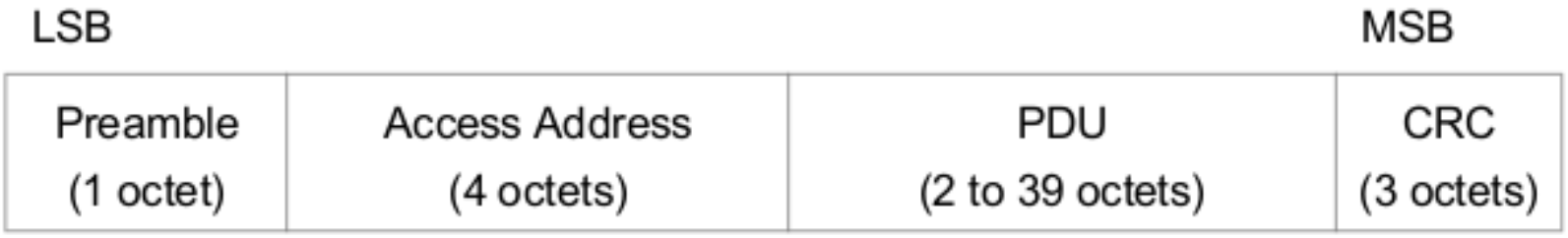
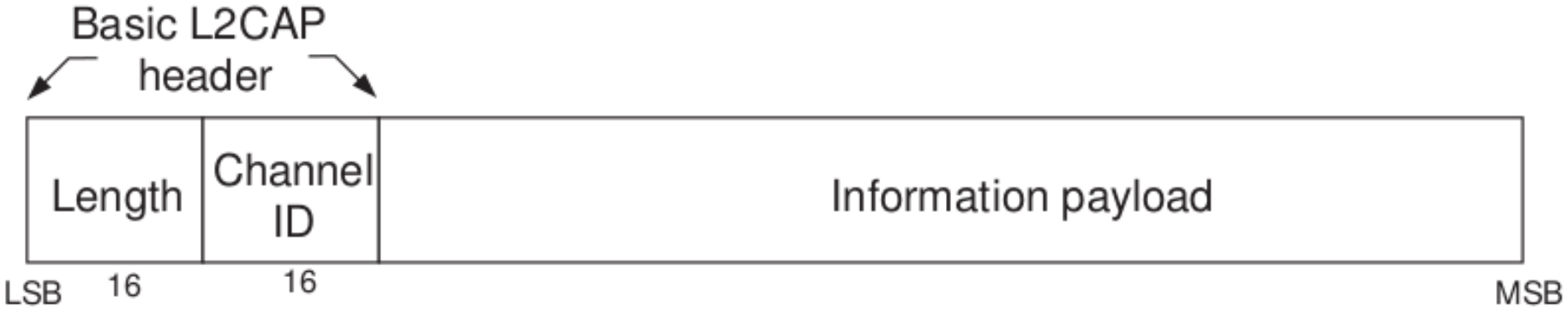


Figure 2.1: Link Layer packet format

- Min of 2 bytes due to 2 byte header
- LLID: Control vs Data
- Length

L2CAP: A Few ~~Bytes~~ Octets of Bloat



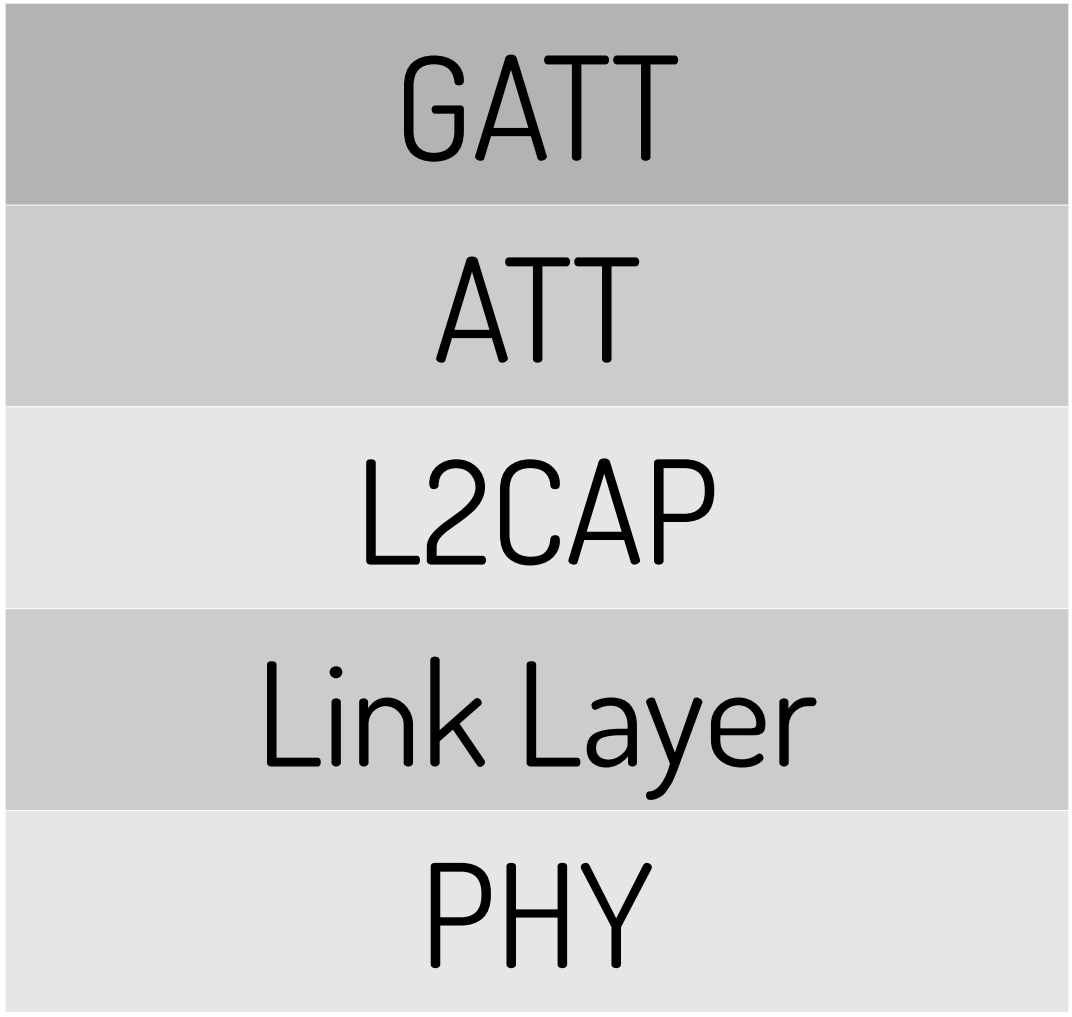
ATT/GATT

- Services: groups of characteristics
- Characteristics
  - Operations
- Everything identified by UUID
  - 128 bit
  - Sometimes shortened to 16 bits

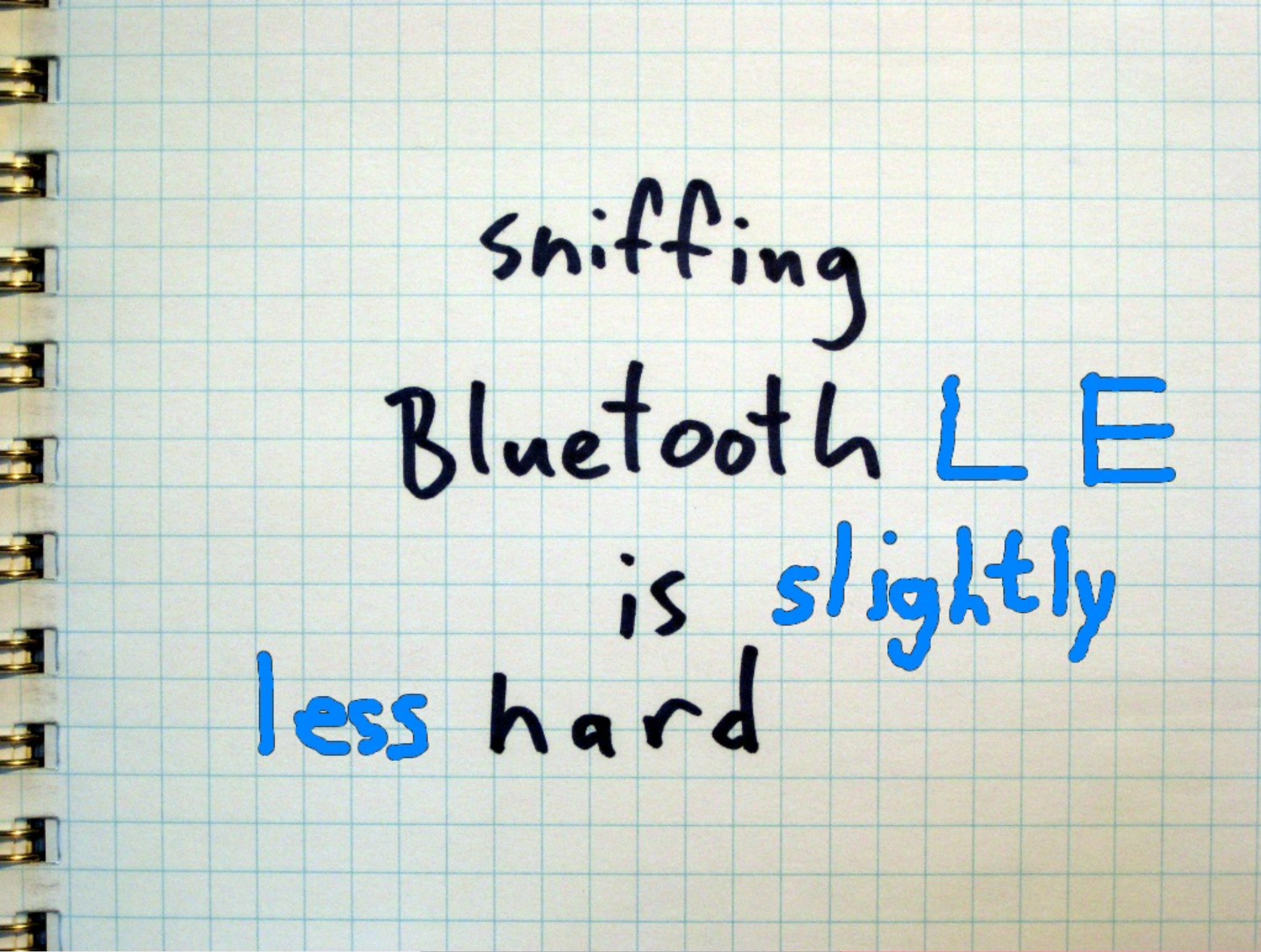
Example GATT Service: Heart Rate

- Service: `0x180D`
- Characteristic 1: `0x2A37` – Heart Rate
  - Can't read or write
  - Notify: subscribe to updates
- Characteristic 2: `0x2A38` – Sensor Location
  - Readable: 8 bit int, standardized list
- Other characteristics: `0x2803`, `0x2902`, ...

Recap

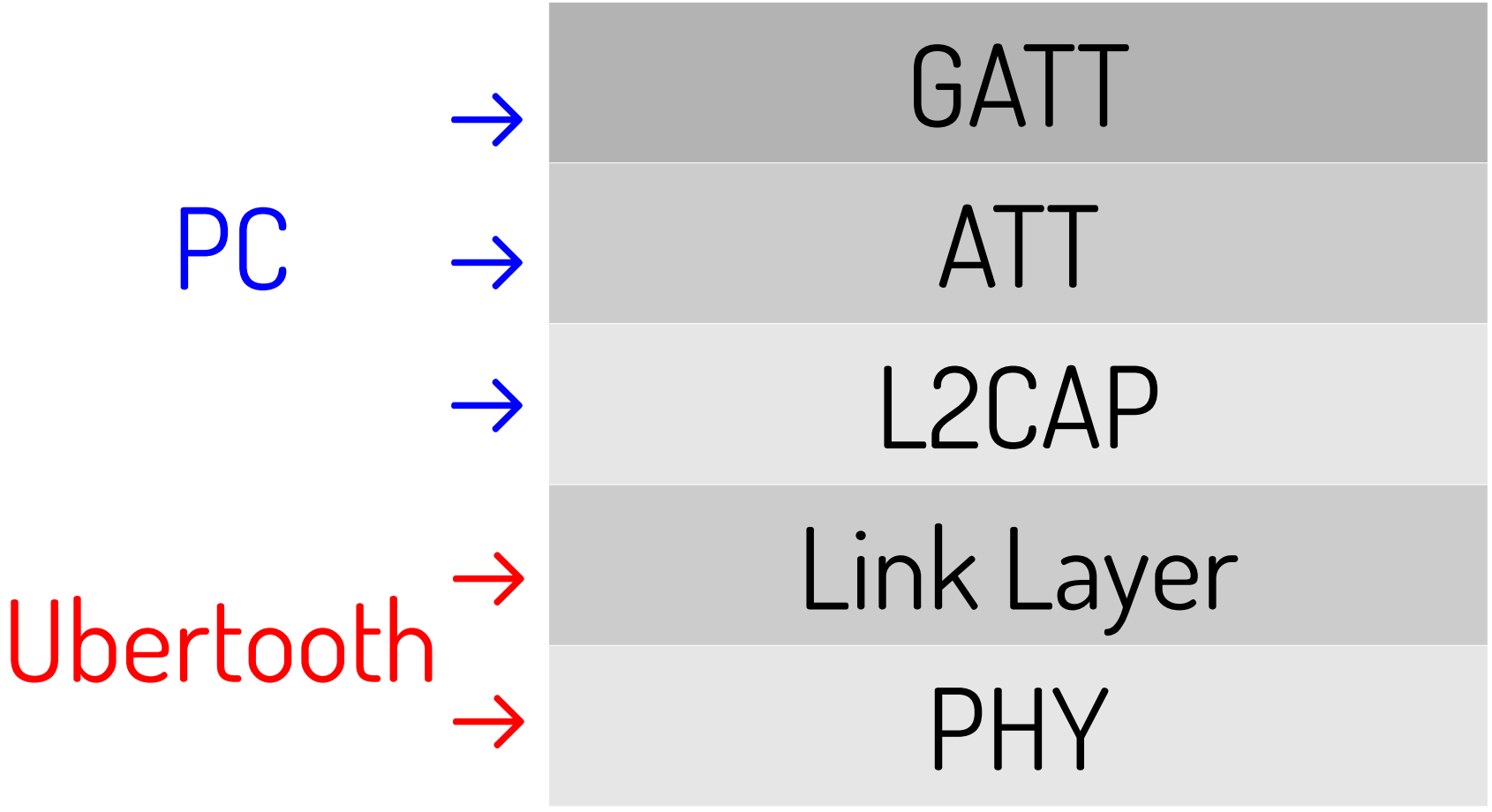



sniffing
Bluetooth
is
hard

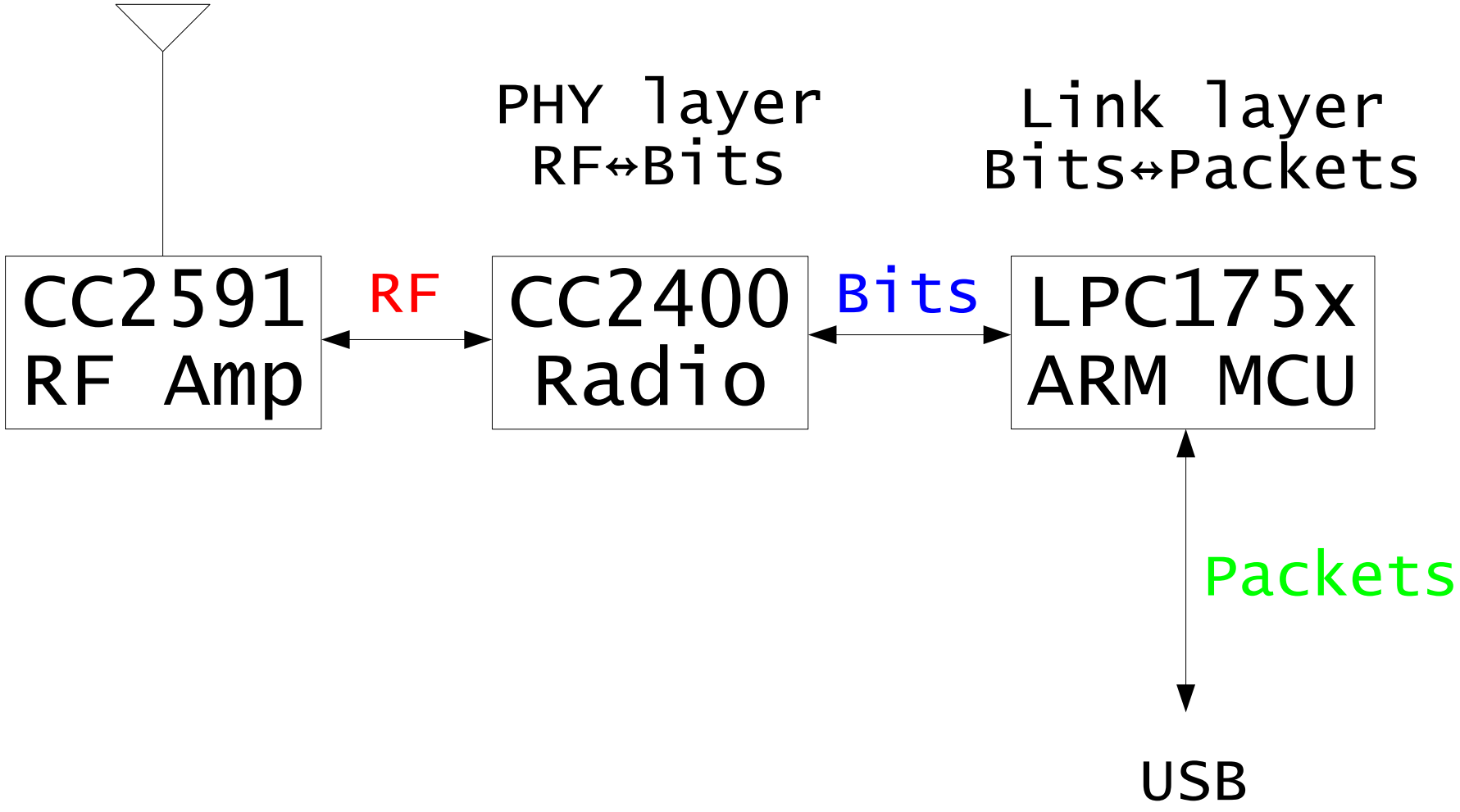

sniffing
Bluetooth LE
is slightly
less hard

How do we sniff it?

Start at the bottom and work our way up:



Ubertooth Block Diagram



Capturing Packets

- Configure CC2400
  - Set modulation parameters to match Bluetooth Smart
  - Tune to proper channel
- Follow connections according to hop pattern
  - Hop increment and hop interval, sniffed from connect packet or recovered in promiscuous mode
- Hand off bits to ARM MCU

Link Layer

Figure 2.1: Link Layer packet format

What we have: Sea of bits

What we want: Start of PDU

What we know: AA

CC2400 does this

FO FREE

10001110111101010101
10011100001000110011
11100100110100011101

PHY Layer.. Link Layer..

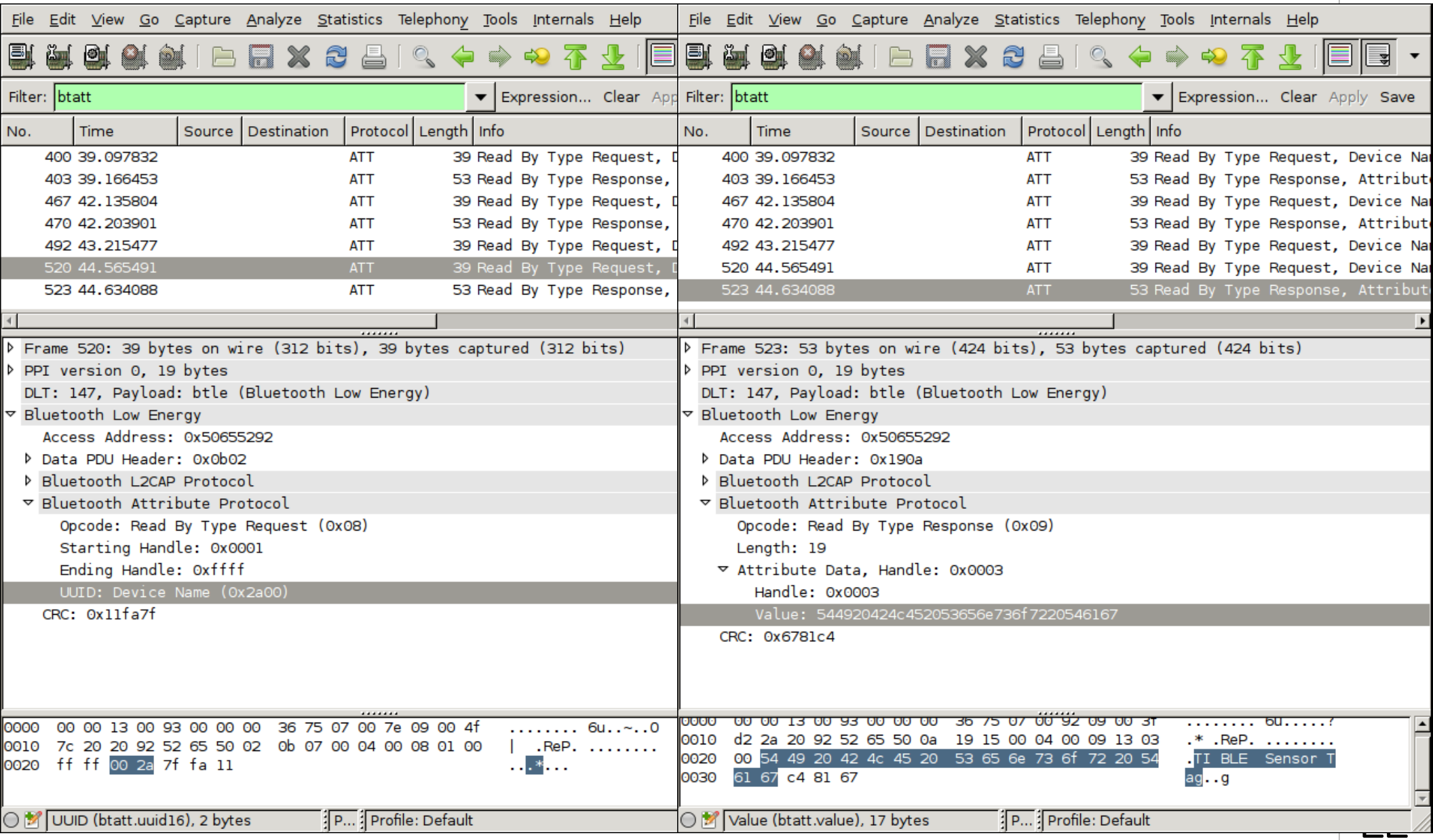
We converted RF to packets
Now what?

Capturing Packets... To PCAP!

- ubertooth-btle speaks packets
- libpcap → dump raw packet data
- PPI header (similar airodump-ng and kismet)

- We have a DLT for Bluetooth Smart
  - Unique identifier for the protocol
  - Public release of Wireshark plugin Coming Soon™

Wireshark Awesomeness



Encryption

- Provided by link layer
- Encrypts and MACs PDU
- AES-CCM

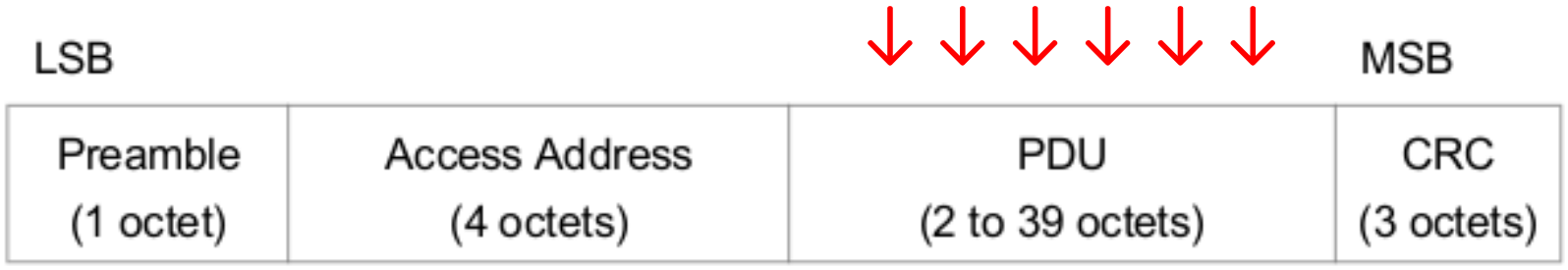


Figure 2.1: Link Layer packet format

Key Exchange

Custom Key Exchange Protocol

- Three stage process
- 3 pairing methods
  - Just Works™
  - 6-digit PIN
  - OOB
- "None of the pairing methods provide protection against a passive eavesdropper" -Bluetooth Core Spec

Cracking the TK

```
confirm
=
AES(TK, AES(TK, rand XOR p1) XOR p2)
```

```
GREEN = we have it
  RED = we want it
```

TK: integer between 0 and 999,999

Just Works™: always 0!

Cracking the TK – With *crackle*

Total time to crack:

< 1 second

And That's It

- TK → STK
- STK → LTK
- LTK → Session keys

KEY EXCHANGE = BROKEN

100% PASSIVE

The Ugly

LTK Reuse

LTK Reuse

- Good for security: pair in a faraday cage
- Counter-mitigation: Active attack to force re-pairing

Decrypting

- Assumption: Attacker has LTK – reused!
- Procedure
  - Attacker passively capturing packets
  - Connection established
  - Session information captured

Decrypting – With *crackle*

- Yes, crackle does that too!
- crackle will decrypt
  - a PCAP file with a pairing setup
  - a PCAP file with an encrypted session, given an LTK

The Ugly: Recap

- Key exchange broken
- LTK reuse means all communication is effectively compromised

- 99% passive
  - Worst case scenario: one active attack with off-the-shelf hardware

The Fix

Secure Simple Pairing

My Qualifications

- Infosec Researcher
- Infosec Consultant
- Occasional programmer
- Husband
- Able to grill a mean steak

Shameless Plug:

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NOT LISTED: Cryptographer

Why Secure Simple Pairing?

- Eavesdropping protection: ECDH
- In production since 2007, only one weakness
- Downside: ECDH is expensive
  - secp192r1: ~5 seconds on 8-bit CPU
  - No open source implementation (until now)

The Five Phases of SSP

1. Public key exchange
2. Authentication Stage 1
3. Authentication Stage 2
4. Link Key Calculation
5. LMP Authentication and Encryption

SSP in Bluetooth Smart

1. Public key exchange
2. Authentication Stage 1: Numeric comparison only
3. Authentication Stage 2
4. Link Key Calculation
5. ~~LMP Authentication and Encryption~~

Backward Compatibility

- OOB not broken
- Use calculated link key as 128-bit OOB data
- Most chips have support

Demo

- D
  - e
    - m
      - o

Am I Affected?

- Probably
- Exception: Some vendors implement their own security on top of GATT
  - Did they talk to a cryptographer?

Summary

- The Good: Bluetooth Smart
- The Bad: Key Exchange
- The Ugly: LTK Reuse
- The Fix: SSP

Capabilities

- Ubertooth
  - Passively intercept Bluetooth Smart
  - Promiscuous mode and injection (not discussed)
- Wireshark plugins
- crackle
  - Crack TK's sniffed with Ubertooth
  - Decrypt PCAP files with LTK
- nano-ecc: 8-bit ECDH implementation

Software

- Ubertooth and libbtbb
  - http://ubertooth.sourceforge.net/
- nano-ecc (8-bit ECDH and ECDSA)
  - https://github.com/iSECPartners/nano-ecc
- crackle
  - http://lacklustre.net/projects/crackle/

Thanks

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#ubertooth on freenode
bluez
Bluetooth SIG

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Thank You

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Feedback

Please scan badge when leaving

Thanks again!