

Mini-RFC: MiniTelemetry Protocol v1.0

1. Introduction

Protocol Name: MiniTelemetry v1.0

Purpose:

MiniTelemetry is a lightweight protocol for transmitting telemetry data from IoT devices to a centralized server using UDP. It supports batching of readings, heartbeat messages for liveness detection, and handles packet loss, duplication, and reordering.

Use Case:

- Collecting temperature and humidity readings from distributed IoT devices.
- Efficient periodic reporting with minimal network overhead.

Motivation:

Existing protocols like MQTT or CoAP often rely on TCP or introduce significant overhead. MiniTelemetry provides a simple, UDP-based solution with reliability features including ACKs, retransmissions, and a reordering buffer.

Assumptions & Constraints:

- Maximum packet size ~2 KB (UDP).
- Default reporting interval is 2 seconds.
- Packet loss is tolerated; retransmission ensures eventual delivery.
- Each device has a unique DeviceID and sequential SeqNum.

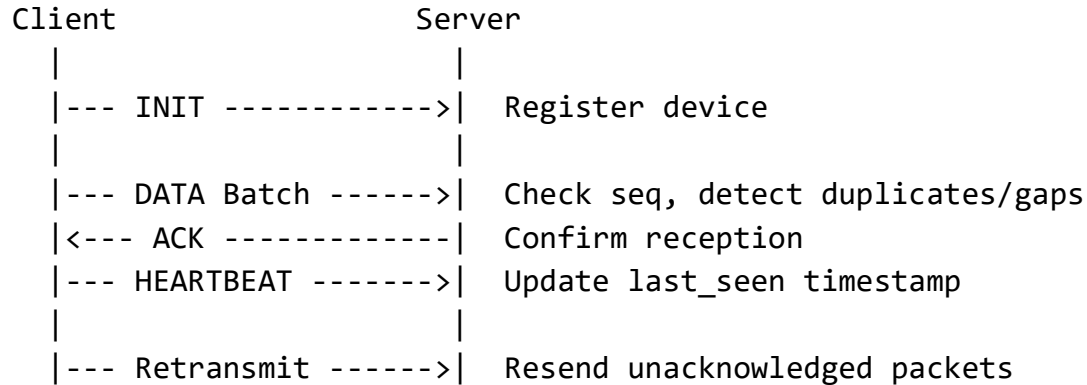
2. Protocol Architecture

Entities:

1. **Client/Device:** Sends telemetry data (DATA) and heartbeat messages.

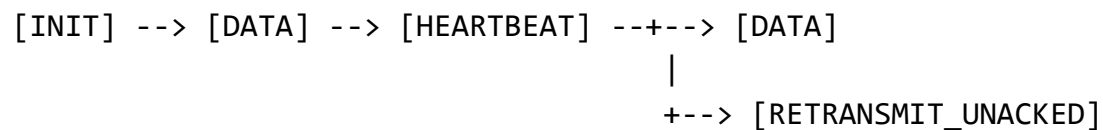
2. **Server:** Receives packets, validates sequence numbers, detects duplicates or gaps, logs readings to CSV, and sends ACKs.

Sequence Flow (ASCII Diagram):

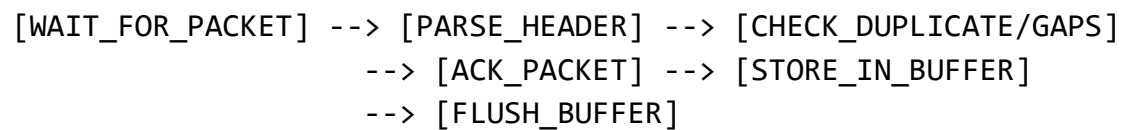


Finite-State Machine (simplified):

Client FSM:



Server FSM:



3. Message Formats

Header (10 bytes total):

Field	Size (bits)	Description	Byte Offset
Version	4	Protocol version (v1 = 1)	0
MsgType	4	0=INIT,1=DATA,2=HEARTBEAT,3=ACK	0

DeviceID	16	Unique device identifier	1–2
SeqNum	16	Sequence number	3–4
Timestamp	32	Unix epoch seconds	5–8
BatchCnt	8	Number of readings in payload	9
Padding	16	Reserved for alignment	10–11

Payload (12 bytes per reading):

Field	Size (bits)	Description
Temp	32	Celsius
Humidity	32	% RH
TS	32	Reading timestamp

Struct packing examples:

```
# Header
header = struct.pack("!B H H I B 2x",
                    msg_type,
                    device_id,
                    seq,
                    timestamp,
                    batch_count)
```

```
# Payload
for (t, h, ts) in batch:
    payload += struct.pack("!f f I", t, h, ts)
```

Notes:

- batch_count allows multiple readings per UDP packet.
- Padding ensures proper 4-byte alignment for payload parsing.

4. Communication Procedures

Session Start (INIT):

- Device sends INIT message → Server registers device with DeviceID and initial SeqNum.

Normal Data Exchange (DATA):

1. Device collects telemetry readings and groups them into batches.
2. Device sends DATA packet with batch_count > 0.
3. Server checks for duplicates (SeqNum ≤ last_seq) and gaps (SeqNum - last_seq > 1).
4. Server stores readings in a reordering buffer (250 ms window) and sends ACK.

Heartbeat (HEARTBEAT):

- Sent periodically every 5 seconds.
- Server updates last_heartbeat timestamp to detect offline devices.

Error Recovery / Retransmission:

- Device keeps unacknowledged packets in unacked_packets.
- Timeout = 3 s → retransmit if ACK not received.
- Duplicate and gap flags recorded for metrics.

Session Shutdown:

- Optional; client can stop sending data. Server continues logging until process termination.

5. Reliability & Performance Features

- **Retransmission:** Timeout-based (3 s), unacked packets are resent.
- **Duplicate Detection:** SeqNum ≤ last_seq → marked as duplicate.
- **Gap Detection:** SeqNum - last_seq > 1 → sequence gap counter incremented.
- **Reordering Buffer:** 250 ms window to sort out-of-order readings before CSV storage.
- **Metrics Collected:**
 - Bytes per report
 - Packets received
 - Duplicate rate

- Sequence gaps
- CPU time per report

6. Experimental Evaluation Plan

Metrics:

- Duplicate rate, sequence gap count, bytes per report, CPU per report.

Baselines:

- Compare single-reading packets vs. batch packets (--batch parameter).

Network Simulation (Linux netem):

baseline

```
./test_netem.sh baseline
```

Results :

```
=== TEST COMPLETED ===
```

```
=== Metrics Summary ===
```

```
bytes_per_report: 20.00
```

```
packets_received: 14
```

```
duplicate_rate: 0.000
```

```
sequence_gap_count: 0
```

```
cpu_ms_per_report: 0.616
```

5% packet loss :

```
./test_netem.sh loss  
sudo tc qdisc add dev $IFACE root netem loss 5%
```

Results :

=== TEST COMPLETED ===

=== Metrics Summary ===
bytes_per_report: 19.07
packets_received: 33
duplicate_rate: 0.364
sequence_gap_count: 2
cpu_ms_per_report: 0.126

100 ms delay with 10 ms jitter

```
sudo tc qdisc add dev $IFACE root netem delay 100ms 10ms
```

Results :

=== TEST COMPLETED ===

=== Metrics Summary ===
bytes_per_report: 19.90
packets_received: 27
duplicate_rate: 0.000
sequence_gap_count: 0
cpu_ms_per_report: 0.427
Cpu usage is higher because of delay

7. Example Use Case Walkthrough

- **Session Start:**
 - Device 103 sends INIT (Seq 1) → Server registers.
- **Data Batch:**
 - Device sends batch of 10 readings:

```
100,11,1766427006,1766427024.942385,0,0,26.92,69.19
100,11,1766427008,1766427024.942385,0,0,24.99,66.09
100,11,1766427010,1766427024.942385,0,0,28.93,53.59
100,11,1766427012,1766427024.942385,0,0,25.38,56.46
100,11,1766427014,1766427024.942385,0,0,21.93,67.4
100,11,1766427016,1766427024.942385,0,0,31.48,49.79
100,11,1766427018,1766427024.942385,0,0,34.04,48.27
100,11,1766427020,1766427024.942385,0,0,32.15,43.21
100,11,1766427022,1766427024.942385,0,0,32.83,52.28
100,11,1766427024,1766427024.942385,0,0,30.98,59.49
```

4 heartbeats then a 10 readings batch

- Server buffers readings, sorts by payload timestamp, writes to CSV.
- **Heartbeat:**
 - Device sends heartbeat every 5 s → Server updates last_seen.

8. Limitations & Future Work

- Only supports one-way telemetry; no full TCP-like reliability.
- No encryption or authentication.
- Heartbeat only indicates liveness, not full connection health.
- Future improvements:
 - Adaptive batching
 - Forward Error Correction (FEC)
 - Secure transport (TLS/DTLS)
 - Configurable reorder window

9. References

1. [RFC 768 – User Datagram Protocol \(UDP\)](#)
2. MQTT Protocol Specification
3. Python struct documentation: <https://docs.python.org/3/library/struct.html>
4. Linux tc/netem: <https://wiki.linuxfoundation.org/networking/netem>