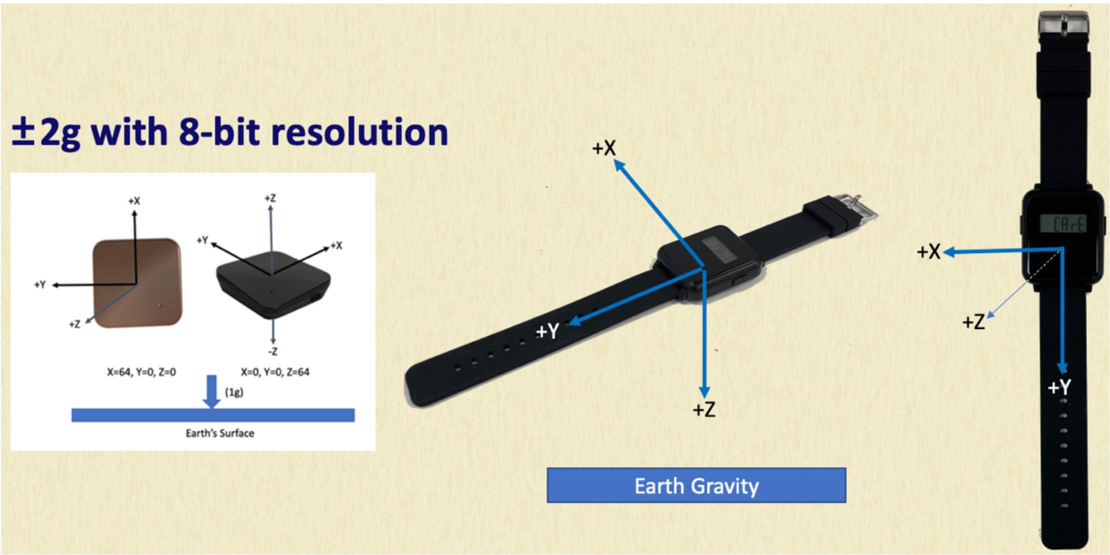
G3MR Advertising & Sampling V2

This document is for G3MR firmware 3mr.06.60 or later ONLY

G3MR is the Band for the Senior Care Researchers. The advertising format supports the following features:

- Motion Raw Information
- Different broadcasting frequencies to save battery energy

G3 Accelerometer Position



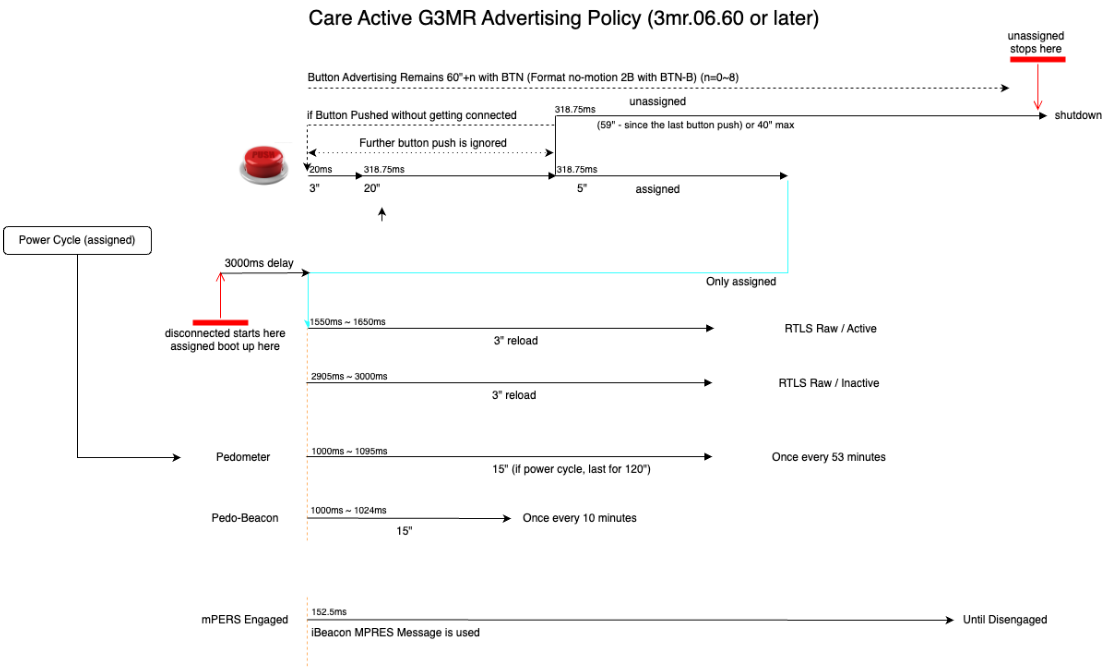
The range of values for each axis is from -128 to 127, representing -2g to +1.984g. When a Care Watch is placed stationary on a desktop with its LCD facing up, its accelerometer reading is (X, Y, Z) = (0, 0, 64).

Advertising Scheme

The watch uses the following advertising scheme to broadcast activity information to nearby stations. Stations that detect these activity packets upload the information to the cloud. The cloud then processes this information to generate these visualizations:

- Indoor Location Distribution
- ActiGraph
- Motion reconstruction

Please note: Not every packet will be received by stations, as packet loss is possible.



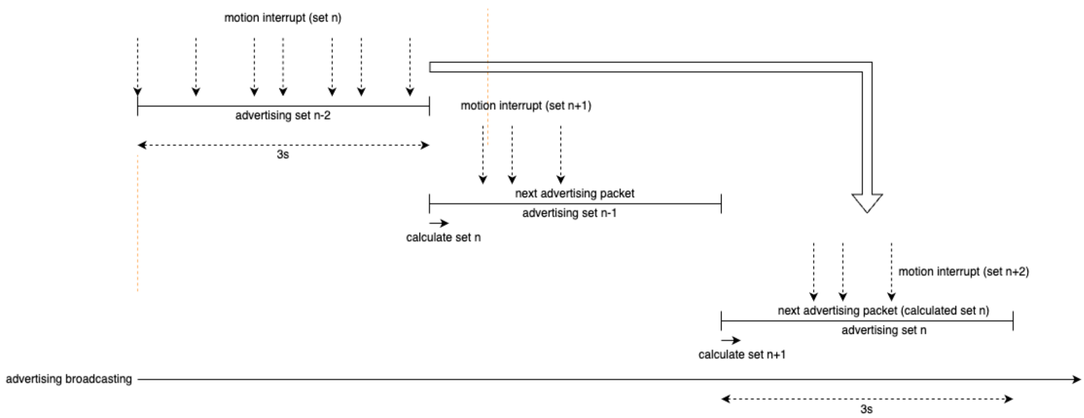
(Refer to G3MR Advertising Policy Document for more details.)

Sampling

Sampling Rate

The watch begins sampling the accelerometer based on motion interrupts, which are triggered by a ±0.0625g force on the accelerometer. Motion data is captured and grouped into 3-second advertising sets. A single advertising packet can store up to five sets of motion raw data and one accumulated motion vector length (ACVL).

The calculation for each set occurs in the next 3-second period after the motion interrupts are collected. For example, while advertising set n is being broadcast, the device calculates set n+1, which contains the motion data from the previous 3-second period. This creates a sequential pipeline where data collection, calculation, and broadcasting are offset by one 3-second interval.
This timing mechanism creates a consistent delay between when motion events occur and when their corresponding data is broadcast. As shown in the diagram, while advertising set n-2 is being broadcast, motion interrupts for set n+1 are being collected, and set n is being calculated.



Accelerometer Parameters

- Output Data Rate (ODR): 12.5Hz
- Output Data Rate for Wake Up Function (OWUF): 12.5Hz
- Interrupt Trigger Force: ±0.0625g
- Wake Up Counter: 1 (Requires one additional threshold check after trigger)

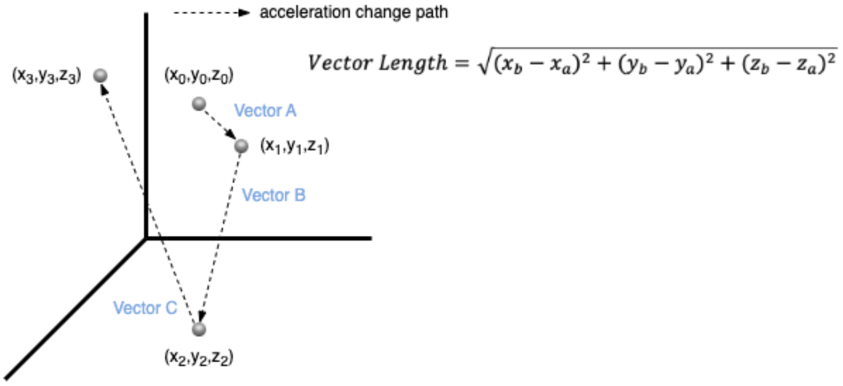
Settings of Active Sampling

- Minimum Interrupt Trigger Interval: 100ms (no further interrupts in this time range regardless what ODR and OWUF are set)
- Active Sampling Collection Interval: 3s
- Maximum Sets of Active Sampling per Packet: 5 sets of (x,y,z) and 1 accumulated motion vector length.

Vector Length

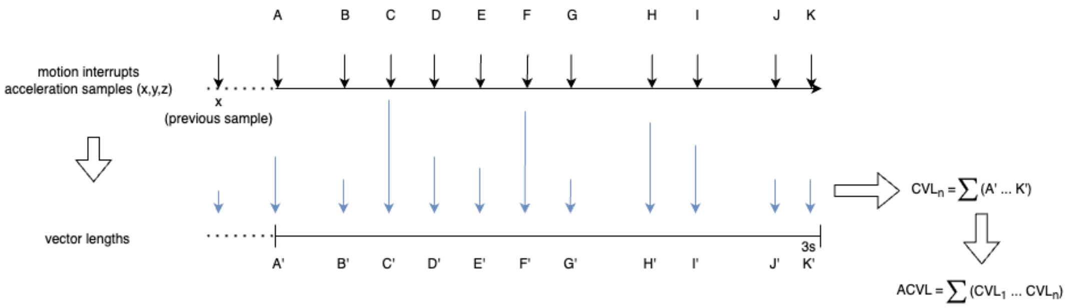
Vector length is used for the following purposes.

- Key points selection
- Per-packets CVL (Cumulative Vector Lengths)
- A-CVL (Accumulated CVL)



For example, Vector A = $\sqrt{(x_1 - x_0)^2 + (y_1 - y_0)^2 + (z_1 - z_0)^2}$

The sum of vector lengths in a 3-second sampling collection interval is the per-packet CVL (Cumulative Vector Length). To compensate for possible packet loss, CVL values are continuously accumulated into the A-CVL (Accumulated CVL) until the 3-byte integer overflows.



Assume each captured motion acceleration point is labeled P_0 ... P_n, where P_0 is the last capture point from the previous sampling interval.

Vector Length $V_n = \|P_n - P_{n-1}\|_2$

Cumulative Vector Length $CVL = \sum V_n$

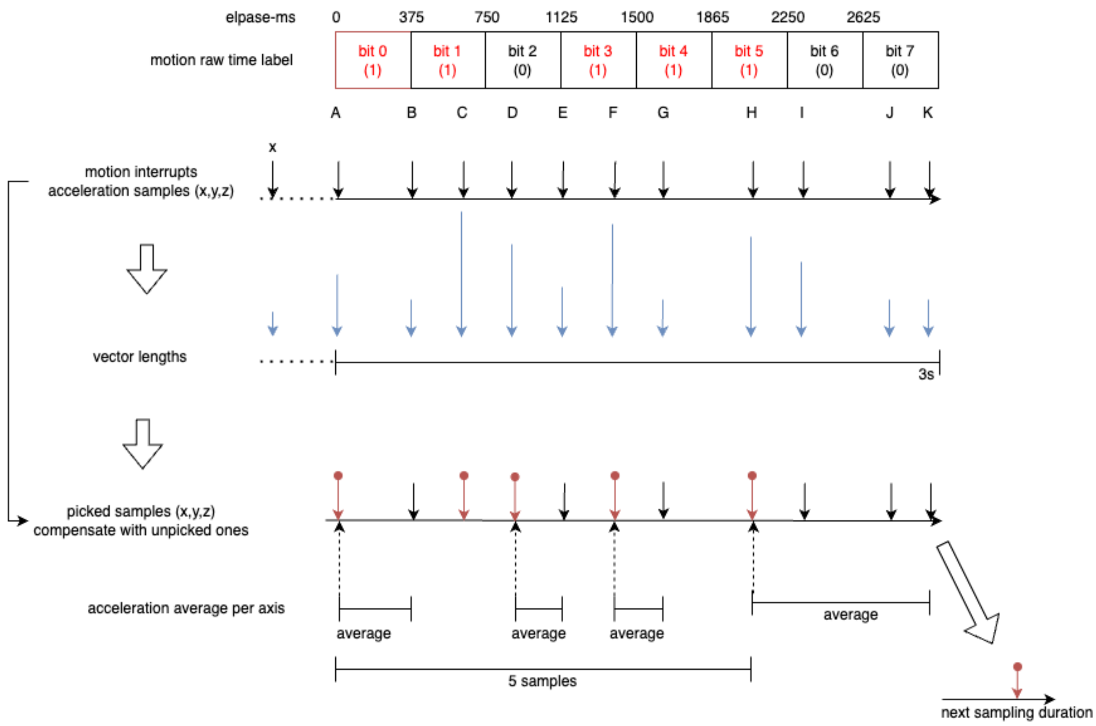
Accumulated CVL $ACVL = \sum CVL_n$

How Sampling Points Are Picked

Since each packet can store only 5 sets of points per 3-second sampling period, it is crucial to select the most significant points for accurate motion reconstruction in the cloud. Point x represents the last captured point from the previous collection period, which serves as the starting point (P_0) for vector length calculations in the current period. The diagram illustrates the point selection process:

1. The top 4 largest vector norms are used to identify key points
2. The first point is a must-select point.
3. Once these points are selected, the unselected points contribute to an average calculation
4. This average is then applied to the selected points

The **Motion Raw Time Label** is an 8-bit value that maps to the 3-second sampling period, as explained in the following section.



Average Applying

Since not all sampled points can be transmitted, an averaging method is used to capture the movement characteristics of the excluded points. The averaging is applied backwards (to previous points) because each selected point is considered to be the starting point of a swing movement in a new direction.

Where:

P_s is the selected point

P_{s+1} ~ P_n are the unselected points before the next selected points or end of sampling period.

$\begin{bmatrix} x \\ y \\ z \end{bmatrix}_{s'}$ is the selected point after averaging with all unselected points, calculated as:

$$\begin{bmatrix} x \\ y \\ z \end{bmatrix}_{s'} = \begin{bmatrix} \frac{\sum_{i=s}^{n} x_i}{n} \\ \frac{\sum_{i=s}^{n} y_i}{n} \\ \frac{\sum_{i=s}^{n} z_i}{n} \end{bmatrix}$$

This method has the following benefits:

- Can smooth out sudden/sporadic noise
- Does not lose extreme value information
- Can better reflect overall motion characteristics

First Captured Point

Since the averaging method is applied backwards, the first motion point P_1 captured in each 3-second cycle is always selected for transmission. This ensures that the start of each new motion sequence is preserved, as subsequent points in the cycle may be averaged with their preceding points.

Vector Length Analysis for Turning Point Detection

During normal hand swings, turning points generate opposing acceleration values (positive/negative) along the x, y, and z axes. Since sampling only occurs with acceleration changes, the superposition of these opposing forces combined with previous acceleration changes produces significant variations.

Vector length magnitude serves as the primary indicator for identifying key turning points, preventing accelerations in similar directions from masking actual turns. This approach makes the identification of key turning points in sampling data more reliable through vector length analysis.

Using vector length calculations provides an additional advantage by eliminating the impact of Earth's gravity from the measurements. Since the gravitational force is constant, the vector length approach focuses solely on the dynamic accelerations caused by motion, ensuring more accurate motion analysis without gravitational interference.

Taking the following simulation sample points:

Point 0 ~ 4: start moving left (X axes)

{30, 0, 64}, {32, 0, 64}, {35, 0, 64}, {33, 0, 64}, {30, 0, 64}

Point 5 ~ 9: going left-backward (XY Plane)

{28, 5, 64}, {25, 10, 64}, {20, 15, 64}, {15, 20, 64}, {10, 25, 64}

Point 10 ~ 14: then going backward (Y axes)

{0, 30, 64}, {0, 32, 64}, {0, 35, 64}, {0, 33, 64}, {0, 30, 64}

Point 15 ~ 19: going upper-left-backward (XYZ space)

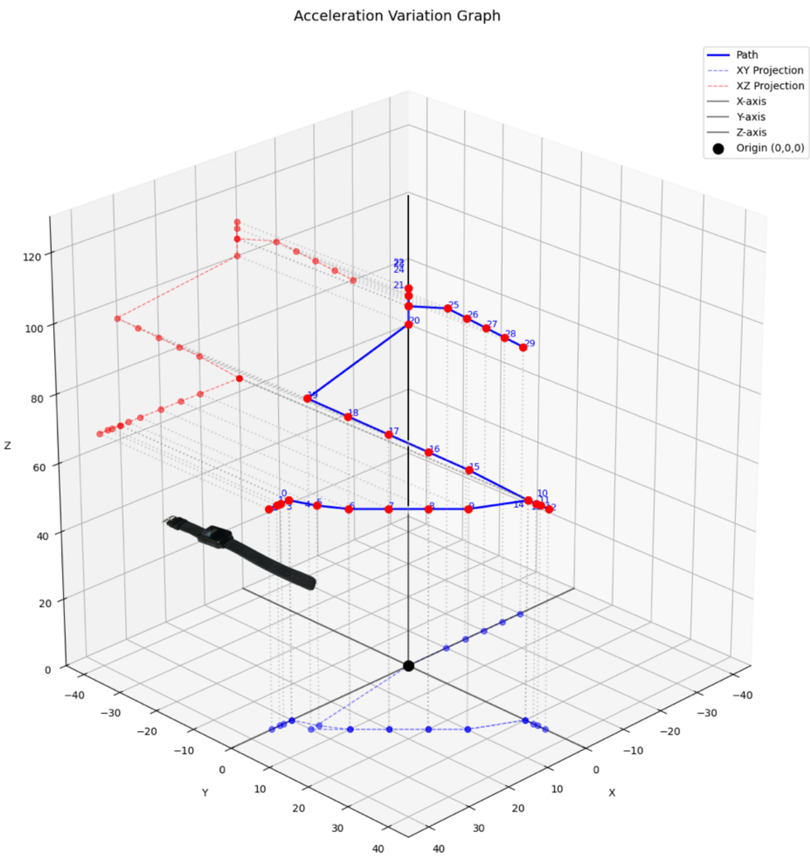
{10, 25, 75}, {15, 20, 80}, {20, 15, 85}, {25, 10, 90}, {30, 5, 95}

Point 20 ~ 24: going up (Z axes)

{0, 0, 100}, {0, 0, 105}, {0, 0, 110}, {0, 0, 108}, {0, 0, 105}

Point 25 ~ 29: going right-down (XY plane)

{-10, 0, 100}, {-15, 0, 95}, {-20, 0, 90}, {-25, 0, 85}, {-30, 0, 80}



Please note, this is not position in 3D space but the acceleration change diagram.

```
[0->1]: norm=4
[1->2]: norm=9
[2->3]: norm=4
[3->4]: norm=9
[4->5]: norm=29
[5->6]: norm=34
[6->7]: norm=50
[7->8]: norm=50
[8->9]: norm=50
[9->10]: norm=125
[10->11]: norm=4
[11->12]: norm=9
[12->13]: norm=4
[13->14]: norm=9
[14->15]: norm=246
[15->16]: norm=75
[16->17]: norm=75
[17->18]: norm=75
[18->19]: norm=75
[19->20]: norm=950
[20->21]: norm=25
[21->22]: norm=25
[22->23]: norm=4
[23->24]: norm=9
[24->25]: norm=125
[25->26]: norm=50
[26->27]: norm=50
[27->28]: norm=50
[28->29]: norm=50
```

Picked Points:

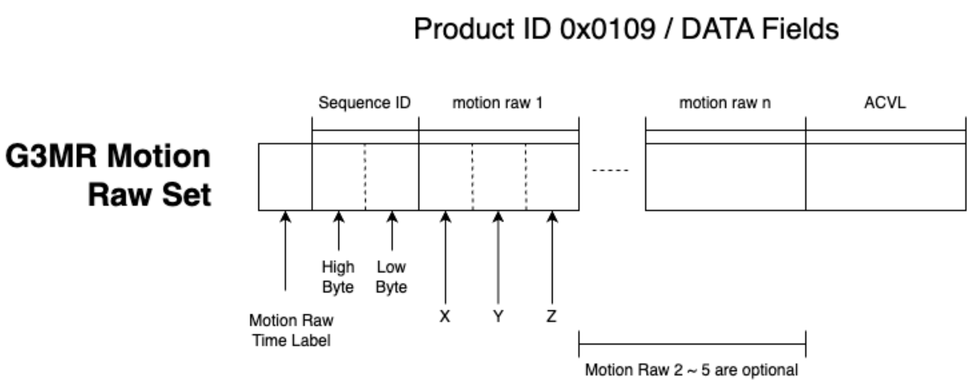
- Point 0 (This is a MUST-PICK point)
- Point 10 (norm = 125)
- Point 15 (norm = 246)
- Point 20 (norm = 950)
- Point 25 (norm = 125)

G3MR Motion Raw Advertising Format

0x02,
GAP_ADTYPE_FLAGS,
GAP_ADTYPE_FLAGS_LIMITED | GAP_ADTYPE_FLAGS_BREDR_NOT_SUPPORTED,
0x1A, // or 0x0B for inactive mode
GAP_ADTYPE_MANUFACTURER_SPECIFIC,
LO_UINT16(TRACMO_COMPANY_ID), // 0xF7
HI_UINT16(TRACMO_COMPANY_ID), // 0x05
0x01, // G3MR, Product ID High
0x09, // G3MR, Product ID Low
Motion_Raw_Set // Associate data based on the product

Motion Raw

A single advertising packet can contain up to five sets of Motion Raw data. In the absence of any current motion detection, the packet will include the most recently triggered Motion Raw sample.



X/Y/Z are 2’s complement, which is 127 ~ -128.

Sequence ID

Each packet containing collected samples is assigned a sequence ID. When the device powers on, the initial sequence ID is randomly generated. Subsequently, the sequence ID increments with each new packet.

Motion Raw Time Label

The Motion Raw Time Label aids in motion reconstruction by enabling the simulation software to estimate the timing of selected points with a resolution of 375ms. The time label is an 8-bit value that maps to the 3-second sampling period:

- Each bit represents a 375ms time interval (3000ms ÷ 8 = 375ms)
- A bit value of 1 indicates there is at least one selected point within that 375ms interval
- A bit value of 0 indicates no points were selected in that interval
- Final value combines time labels of all selected points using OR mask

ACVL

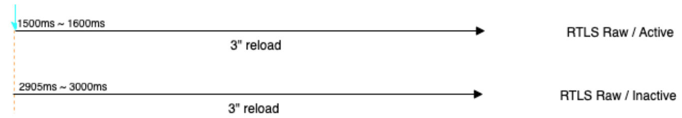
ACVL (Accumulated CVL) is a rolling accumulator of all generated vector lengths. The purpose of ACVL is to enable ActiGraph generation despite potential packet loss. For example, when generating an ActiGraph with 1-minute resolution, the loss of a few 3-second interval packets is tolerable. Even with more extensive packet loss, interpolation can be used to reconstruct the ActiGraph for time periods where packets were lost.

The ACVL (Accelerometer Value) field always follows the last motion raw data in the packet. It is a 3-byte unsigned integer stored in little-endian format. For example:

- If the packet contains only one motion raw dataset, the ACVL field immediately follows that motion raw data
- The ACVL field length remains constant at 3 bytes regardless of how many motion raw datasets are present

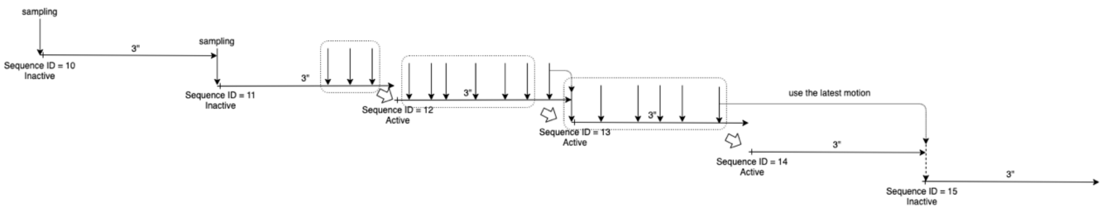
Active Mode and Inactive Mode

All motion data are collected by the triggered motion interrupts. The advertising timer makes the motion sampling into continuous 3-second time slots. If there is any motion captured, it will be advertised in the next advertising slot with a faster interval (active mode). If there is no motion captured, the next advertising slot will use a slower interval for advertising the latest captured motion data (inactive mode).



Active/Inactive Mode Switching

Since the active mode is determined by the motion interrupt of the accelerometer, the mode switched between active and inactive is based on whether there is any motion captured before a new adverting slot begins.



Pedometer

The pedometer uses the same motion activity samples to calculate steps. The current pedometer algorithms focus on detecting steps within a speed range of:

- 86 BPM (700ms per step) to 140 BPM (500ms per step)

Step speeds outside this range (slower than 86 BPM or faster than 140 BPM) are typically filtered out, as they can be confused with other activities that produce similar motion patterns, such as:

- Driving
- Typing
- Making espresso

Revision History

V1.0/2023-March-22

Init Version

Extracted from the G3M Adv Format document

V1.1/2023-March-29

Redefined the active mode and inactive mode with the accelerometer interrupt

V2.0/2023-April-17

Use only motion interrupt to complete the active sampling

V3.0/2023-April-19

Making active and inactive switch synchronous by the fixed 3-second time slots

V3.1/2023-April-25

Removed statistics inquiry feature

V3.2/2024-September-13

Fixed the packet format error

V4.0/2024-Dec-26

Sampling algorithms version 2

V4.1/2025-Jan-24

Revised with the new accelerometer parameters

V4.2/2025-Feb-18

Added pedometer descriptions