

CoinGecko Price Aggregation Methodology

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1 Version History

Version No	Version Date	Changes to Previous
v1.0	February 14, 2019	Initial documented version on our website
v2.0	October 6, 2023	Amendments to BPI and Improved Outlier Detection
v2.1	August 1, 2024	Improvements to Outlier Detection, and Utilization of USD_ONRAMP indices to resolve USDT and USDC in pathfinder algorithm

2 Introduction

While CoinGecko provides a wide variety of data across many coins, one of the most important is the price of coins, which we aggregate across a broad range of centralized and decentralized exchanges. After taking in data from multiple sources, we apply a comprehensive algorithm to determine the aggregated market price of any particular coin listed on CoinGecko.

The overall price aggregation methodology is divided into two parts: -

1. a process to calculate the reference bitcoin conversion rate for all tickers, known internally as the Bitcoin Price Index (BPI), and
2. a process to calculate the aggregate market price for all coins listed on CoinGecko.

The BPI is crucial for CoinGecko as all ticker data e.g. price and volume, across all coins, are stored in BTC base before being processed further. Once ticker data is available for coins, we then aggregate said data to calculate the market price, after removing outliers.

This document describes both processes in detail, with calculation examples provided at the end.

3 Raw Ticker Data Collection

CoinGecko collects all available price and liquidity data across all tickers on all exchanges integrated to CoinGecko. For every coin, each exchange and corresponding tickers are manually mapped by our Operations team to the right coin, with particular attention paid to cases of multiple ticker symbols referring to the same coin (e.g. BTC and XBT for bitcoin), or duplicate coin ticker symbols for different coins (e.g. PEPE being used to refer to a myriad of coins). For duplicate coin ticker symbols, our Operations team checks against information on the exchange to ensure that the right tickers are mapped to the right coins.

For the purposes of price aggregation:

1. The current aggregated price only takes into account data from spot exchanges (both centralized and decentralized).
2. Tickers include all pairs and not just limited to fiat or stablecoin pairs.
3. We currently snapshot data from exchanges every 1 minute before preparing and aggregating the price.
4. Once we begin to collect ticker data, they are individually displayed on our Coins page under the Markets tab.

4 Bitcoin Price Index (BPI)

Before aggregating the price of all other coins on CoinGecko, we first calculate the BPI, which serves as the reference conversion rate in converting ticker data for all other coins into BTC base.

4.1 BPI Calculation

1. The BPI is calculated as the volume weighted average price (VWAP) of selected BTC/USD, BTC/USDT, BTC/USDC, or BTC/EUR tickers across a selection of reputable exchanges (*see list of exchanges and tickers in [Appendix A](#)*). While in the past the BPI has taken into account BTC tickers with alternate currencies (such as BTC/KRW for example) to take into account factors such as the kimchi premium, over time given that the market has largely consolidated around trading on USD and USD-denominated stablecoin pairs, we have refined the BPI to its current form to better reflect its role as the reference rate for a large majority of the industry. The BTC/EUR pairs are included as a backup in case of issues with the other tickers, given BTC/EUR's historically tight spread with BTC/USD.
2. For the purpose of BPI calculations:
 - a. Only data from BPI tickers which have been updated within the last 5 minutes are included,
 - b. BPI tickers with $\text{Price}_{\text{USD}}$ equals NaN or Null are excluded,
 - c. BPI tickers whose USD Price deviates from the median of the BPI ticker set by more than 4% are excluded.
3. BPI tickers include BTC/USD, BTC/<non-USD fiat>, BTC/USDT and BTC/USDC pairs. Before performing the VWAP calculation, we need to first convert the non-USD tickers into USD base.
4. For non-USD fiat tickers, e.g. BTC/EUR, we convert the price to USD base using the USD exchange rates from [Open Exchange Rates](#). In case of a failure in obtaining exchange rates from Open Exchange Rates, our platform will automatically fallback to obtaining exchange rates from [Exchange Rates API](#) such that there will be no interruption in the calculation of the BPI.
5. For USDT and USDC tickers within the BPI, we apply a volume weighted aggregated USDT/USD conversion rate ($\text{USD_ONRAMP_INDEX}_{\text{USDT}}$) and USDC/USD conversion rate ($\text{USD_ONRAMP_INDEX}_{\text{USDC}}$) from selected exchanges to account for events of stablecoin depegging (*see list of USD_ONRAMP_INDEX exchanges and tickers in [Appendix B](#) and [Appendix C](#)*).

6. Once all BPI tickers have been converted to USD base, we perform a VWAP calculation to arrive at the $BPI_{BTC/USD}$.
7. From $BPI_{BTC/USD}$ we subsequently apply the corresponding fiat/USD exchange rate from Open Exchange Rates to obtain the BPI for all other fiat currencies supported on CoinGecko, e.g. $BPI_{BTC/EUR}$, $BPI_{BTC/GBP}$, $BPI_{BTC/TRY}$, etc.
8. For reference to how the BPI is calculated, we have provided an [abbreviated example](#) at the end of the document.

4.2 BPI Governance

1. Due to the importance of the BPI, CoinGecko has an internal governance forum that governs the overall BPI methodology, as well as the list of exchanges and tickers used within the BPI calculation. This also includes the methodology, exchanges and tickers for the `USD_ONRAMP_INDEX`.
2. No changes can be made to any part of the BPI as described above, without an explicit majority decision made by the governance forum.
3. The members of the governance forum currently include the following CoinGecko personnel:
 - a. TM Lee, CEO
 - b. Bobby Ong, COO
 - c. Chan Zhong Yang, Head of Research
 - d. Jack Wong, Principal Engineering Manager, Crypto Data Team
 - e. Kristian Kho, Operations Lead
4. The forum meets regularly on a quarterly basis. Emergency meetings of the forum can be called for if circumstances require.
5. Discussions and decisions made during each meeting of the governance forum are recorded in writing to provide an audit trail.

5 Ticker Data Processing

Once the BPI is calculated, we can now process the tickers for all coins listed on CoinGecko. As we have mentioned before, the ticker data collected and stored within CoinGecko are denominated in BTC. Tickers can either be a fiat currency pair, or a crypto-to-crypto pair. We have two different processes to transform them to BTC base.

5.1 Fiat Currency Tickers

For BTC/fiat currency tickers, they are stored as-is in our database. For all other coins, we convert their fiat currency tickers to a BTC base by applying the appropriate BPI conversion rate. Using ETH/USD and ETH/EUR tickers as examples,

$$\text{BTC_PRICE}_{\text{ETH/USD}} = \text{PRICE}_{\text{ETH/USD}} / \text{BPI}_{\text{BTC/USD}}$$

$$\text{BTC_VOLUME}_{\text{ETH/USD}} = \text{VOLUME}_{\text{ETH/USD}} / \text{BPI}_{\text{BTC/USD}}$$

$$\text{BTC_PRICE}_{\text{ETH/EUR}} = \text{PRICE}_{\text{ETH/EUR}} / \text{BPI}_{\text{BTC/EUR}}$$

$$\text{BTC_VOLUME}_{\text{ETH/EUR}} = \text{VOLUME}_{\text{ETH/EUR}} / \text{BPI}_{\text{BTC/EUR}}$$

5.2 Crypto-to-crypto Tickers (Non-fiat Tickers)

Crypto-to-crypto tickers or non-fiat tickers can be grouped into BTC pairs, e.g. ETH/BTC, as well as non-BTC pairs such as ETH/LTC, and also includes stablecoin pairs, e.g. ETH/USDT.

1. For BTC pairs, e.g. ETH/BTC, LTC/BTC etc, they are stored as-is in our database.
2. For non-BTC pairs, we utilize an internal pathfinder algorithm to arrive at the BTC price, similar to how DEXes uses pathfinders to perform a complex swap.
3. Using ETH/LTC as an example, the pathfinder will find the BTC price for ETH using a path of ETH/LTC => LTC/BTC. The more obscure the coin is, the more complex the path may be, e.g. ABC/DEF => DEF/GHJ => GHJ/USDT => USDT/BTC. Once the BTC price is found, it is stored within our database.
4. As this is at the initial stage of ticker data processing, the “paths” are dependent on individual tickers in specific exchanges configured manually by our team, except USDT and USDC.
5. Given the importance of USDT and USDC tickers in resolving paths for other coins, we resolve this using the $\text{USD_ONRAMP_INDEX}_{\text{USDT}}$ and $\text{USD_ONRAMP_INDEX}_{\text{USDC}}$ respectively to USD, before resolving to BTC using BPI_{USD} . The composition of the USD_ONRAMP indices can be found in Appendix B and C.

6. Some examples of paths are as follows:

Coin	Path
DAI	DAI / USD ticker on Coinbase, then convert to BTC using BPI_{USD}
FTM	FTM / USDT ticker on Binance, then convert to USD using $USD_ONRAMP_INDEX_{USDT}$, then convert to BTC using BPI_{USD}
RENBTC	RENBTC / WBTC ticker on Curve, then WBTC / ETH ticker on Kyber Network, then ETH / BTC ticker on Coinbase

7. The pathfinder algorithm applies to both the base or target coin, i.e. the algorithm will work as long as either one of the base or target coin has an identified path to BTC. For example with ticker pair ABC/DEF, it will be able to calculate a BTC-denominated price for the ticker as long as either one of ABC or DEF coin has a path to BTC.

5.3 Displaying Ticker Data

Once the price and volume of all tickers are denominated in BTC, they can then be converted back to USD, or any other fiat currency chosen by the user, to be displayed on our website using the relevant BPI conversion rate.

6 Aggregated Coin Market Price Calculation

While we display individual data for each coin ticker, CoinGecko also displays one aggregated market price for coins. For avoidance of doubt this also includes the aggregated market price for BTC. The methodology to calculate the aggregated market price for a particular coin from its individual tickers is described below.

6.1 Initial Ticker Set Construction

1. An initial ticker set for a particular coin is constructed based on the top 600 tickers of the coin by volume. Tickers outside of the top 600 in volume will not be factored into the later calculation of the aggregated market price.
2. Within this initial ticker set, we also filter out tickers based on the criteria below. The tickers are then marked as anomalies:
 - a. Stale tickers, i.e. tickers where its data has not been updated since 8 hours ago
 - b. $\text{Price}_{\text{USD}}$ equals 0, NaN, or Null
 - c. Volume equals Null
 - d. $\text{Volume}_{\text{USD}}$ equals 0 or Null
 - e. Price or Volume could not be converted to BTC
 - f. Ticker with inflated volume, i.e. the volume of the ticker is more than 5x the volume of the coin from its most recent update (*only applicable to tickers of coins with at least 50BTC in 24H volume*).
3. While every ticker stored in our database is denominated in BTC, to aggregate its price we first convert the ticker prices back to USD.

6.2 Outlier Detection and Exclusion

From the initial ticker set, we apply the appropriate outlier detection algorithms to filter out outliers. We currently implement two different outlier detection algorithms depending on the number of available tickers in the ticker set.

Outlier Detection 1 (For coins with less than three tickers)

For coins with less than three tickers, due to the lack of market data we use a simplified outlier detection algorithm. For these coins, any ticker price change that is greater than 100x from the previous price will cause the ticker to be classified as an outlier.

Outlier Detection 2 (For coins with three tickers or more)

1. For coins with three tickers or more in the ticker set, CoinGecko applies an outlier detection algorithm based on the median absolute deviation (MAD) of the ticker set. To utilize this algorithm, we assume that the ticker set conforms to the [central limit theorem](#), namely that the ticker prices are independently and identically distributed, and tends toward a normal distribution. You can read more about MAD [here](#).
2. Before applying the MAD outlier detection algorithm, we consider an additional condition of whether the coin is:
 - A. listed in less than 5 exchanges, or
 - B. listed in 5 or more exchanges
3. Under Condition A, we utilize the algorithm based on the volume-weighted median and volume-weighted median absolute deviation of the ticker set, whereas under Condition B, we utilize the unweighted median and unweighted median absolute deviation of the ticker set.
4. Consider two ticker sets, Ticker Set A and Ticker Set B which both have three tickers or more. Ticker Set A fulfills Condition A, and Ticker Set B fulfills Condition B. Assume that a , b are tickers within Ticker Sets A and B respectively.
5. For Ticker Set A:
 - i. Calculate the volume-weighted median of the ticker set,
 $\text{MEDIAN} = \text{weighted_median}_{\text{refl}}(\text{PRICE}_{\text{Ticker_a}}, \text{VOLUME}_{\text{Ticker_a}})$ of all a .
 - ii. For each of the tickers, calculate the absolute deviation (ABS) from the volume-weighted median, $\text{ABS}_{\text{Ticker_a}} = \text{PRICE}_{\text{Ticker_a}} - \text{MEDIAN}$ for all a .
 - iii. Calculate the volume-weighted median absolute deviation (MAD) for the entire ticker set, where $\text{MAD} = \text{weighted_median}(\text{ABS}_{\text{Ticker_a}}, \text{VOLUME}_{\text{Ticker_a}})$ for all a .
 - iv. The upper and lower bounds for outlier detection are calculated based on 4 standard deviations from the median. Using the MAD calculated above,
 $\text{LOWER_BOUND} = \text{MEDIAN} - (\text{MAD} * 4)$
 $\text{UPPER_BOUND} = \text{MEDIAN} + (\text{MAD} * 4)$
 - v. In rare occasions where the MAD is sufficiently large, it is possible for the calculated LOWER_BOUND to be negative. In this scenario we will re-calculate the bounds as follows:
 $\text{LOWER_BOUND} = \text{MEDIAN} - (\text{MEDIAN} * 0.3)$
 $\text{UPPER_BOUND} = \text{MEDIAN} + (\text{MEDIAN} * 0.3)$
6. For Ticker Set B instead:

- i. Calculate the (unweighted) median of the ticker set,
 $\text{MEDIAN} = \text{median}(\text{PRICE}_{\text{Ticker}_b})$ of all b .
- ii. For each of the tickers, calculate the absolute deviation (ABS) from the median,
 $\text{ABS}_{\text{Ticker}_a} = |\text{PRICE}_{\text{Ticker}_a} - \text{MEDIAN}|$ for all b .
- iii. Calculate the unweighted median absolute deviation (MAD) for the entire ticker set, where $\text{MAD} = \text{median}(\text{ABS}_{\text{Ticker}_a})$ for all b .
- iv. For coins under Condition B, we consider that they may have significantly more tickers than those under Condition A, and we need to utilize a modified MAD (MMAD) to estimate a sample set's standard deviation. 1.4826 is the consistency constant for normal distribution, hence calculate $\text{MMAD} = \text{MAD} * 1.4826$.
- v. The upper and lower bounds for outlier detection are calculated based on 4 standard deviations from the median. As we are using MMAD to estimate the standard deviation, this gives us:
 $\text{LOWER_BOUND} = \text{MEDIAN} - (\text{MMAD} * 4)$
 $\text{UPPER_BOUND} = \text{MEDIAN} + (\text{MMAD} * 4)$
- vi. In rare occasions where the MAD is sufficiently large, it is possible for the calculated LOWER_BOUND to be negative. In this scenario we will re-calculate the bounds using just the MAD, where:
 $\text{LOWER_BOUND} = \text{MEDIAN} - (\text{MAD} * 4)$
 $\text{UPPER_BOUND} = \text{MEDIAN} + (\text{MAD} * 4)$

If the resulting LOWER_BOUND still returns a negative value, we will re-calculate the bounds again as follows:

$$\begin{aligned}\text{LOWER_BOUND} &= \text{MEDIAN} - (\text{MEDIAN} * 0.3) \\ \text{UPPER_BOUND} &= \text{MEDIAN} + (\text{MEDIAN} * 0.3)\end{aligned}$$

7. We then test every ticker price against the lower and upper bounds. If the price falls outside the bounds, i.e. $\text{PRICE}_{\text{Ticker}_a} < \text{LOWER_BOUND}$ or $\text{PRICE}_{\text{Ticker}_a} > \text{UPPER_BOUND}$, we consider those tickers as outliers and exclude them from the final price aggregation calculation.
8. Do note that we also define a minimum MAD constant of 0.0018. If the calculated MAD from Step 5iii, or calculated MMAD from Step 6iv is lower than the minimum constant, we calculate the lower and upper bound as follows:
 $\text{LOWER_BOUND} = \text{MEDIAN} - (\text{MEDIAN} * 0.3)$
 $\text{UPPER_BOUND} = \text{MEDIAN} + (\text{MEDIAN} * 0.3)$

This minimum constant applies to all coins except stablecoins. Stablecoins will not be subject to this minimum check.

9. When a ticker has been identified as an outlier, the system will automatically add an asterisk * behind the ticker price displayed on the coins' Markets tab.
10. For reference, we have provided examples of the MAD outlier detection for a [Ticker Set A under Condition A](#) and a [Ticker Set B under Condition B](#) at the end of the document.

6.3 Final Price Aggregation

Once outliers have been removed, we calculate the volume weighted average price (VWAP) of all remaining tickers in the ticker set to arrive at the final aggregated price. This is the aggregated market price that is then displayed on our coins page.

7 Manual Intervention / Exception Handling

While we endeavor to use a systematic approach to arrive at the aggregated price, in certain cases manual interventions are required, particularly when it comes to excluding outliers.

1. Once such cases are detected, our operations team will conduct a review to investigate the veracity of certain anomalous tickers.
2. If the team believes a certain ticker price to be anomalous but was not excluded by our outlier detection algorithm, there are several options that the team can undertake:
 - a. The team can unapprove a specific ticker from the coin. This will result in the ticker data to no longer be displayed on the Coin's Markets List, and the ticker will not be taken into account for price aggregation. However the ticker will still be visible on the individual Exchange's page under the "Unverified Tickers" section, but its volume will not count towards the total volume of the exchange.
 - b. The team can blacklist a ticker. This will result in the ticker data to no longer be displayed on the Coin's Market List, as well as the Exchange's page. The ticker will not be taken into account for price aggregation, and its volume will not count towards the total volume of the exchange.
 - c. The team can delist a coin. This will result in all ticker data for the specific coin to be blacklisted (*see 2b above*), and the complete removal of all coin and related ticker data from CoinGecko. No data will be taken into account for any form of calculation.
3. In cases where an entire exchange may be behaving anomalously, our operations team can also manually intervene against exchange data as well:
 - a. If an exchange is behaving anomalously towards a single coin, our operations team can unmap an exchange from a coin. This will give the same result as unmapping a single ticker (*see 2a above*), except across all tickers from the exchange for that specific coin.
 - b. If the exchange is returning anomalous volume or price across most pairs, the team can exclude the volume from that particular exchange. The ticker data will still be visible on Coins pages, but it will not be taken into account for price aggregation. The exchange will still be available if users perform a search, but its volume will not be taken into account towards the total crypto market volume.
 - c. If the issue is more serious, the team can delist an exchange. This will result in the complete removal of all ticker and exchange data from CoinGecko, and no ticker or exchange data will be taken into account for any form of calculation.

4. When a ticker is manually flagged it will be temporarily removed from the ticker list on the coins' Markets tab.
5. Over time should the ticker or exchange eventually recover to normal behavior, our operations team can reverse the steps above so that the ticker data is reincluded in the aggregate price calculation.

8 Calculation Examples

Do note that these are abbreviated examples, and are only meant to be illustrative.

8.1 BPI Calculation Example

Consider a set of BPI tickers and $\text{USD_ONRAMP_INDEX}_{\text{USDT}}$ tickers below:

Ticker 1 - BTC/USDT, 28000 USDT, Binance, Volume: 25000USDT

Ticker 2 - BTC/USD, \$28100, OKX, Volume: \$20000

Ticker 3 - BTC/USD, \$27900, Bitfinex, Volume: \$18000

Ticker 4 - BTC/EUR, €25700, Bitstamp, Volume: €10000

Ticker 5 - USDT/USD, \$1.001, Coinbase, Volume: \$10000

Ticker 6 - USDT/USD, \$1.002, Kraken, Volume: \$8000

As there is a BTC/EUR ticker, we have to first convert it to a USD base using Open Exchange Rates:

$$\begin{aligned}\text{USD_PRICE}_{\text{Ticker 4}} &= \text{PRICE}_{\text{Ticker 4}} * \text{EUR/USD Exchange Rate} \\ &= €25700 * \$1.10 / \text{EUR} \\ &= \$28270\end{aligned}$$

$$\begin{aligned}\text{USD_VOLUME}_{\text{Ticker 4}} &= \text{VOLUME}_{\text{Ticker 4}} * \text{EUR/USD Exchange Rate} \\ &= €10000 * \$1.10 / \text{EUR} \\ &= \$11000\end{aligned}$$

As there is also a BTC/USDT ticker, we also need to convert it to a USD base. We first calculate $\text{USD_ONRAMP_INDEX}_{\text{USDT}}$

$$\begin{aligned}&= \text{VWAP}_{(\text{Ticker 5}, \text{Ticker 6})} \\ &= \text{SUM}(\text{Price} * \text{Volume})_{(\text{Ticker 5}, \text{Ticker 6})} / \text{SUM}(\text{Volume})_{(\text{Ticker 5}, \text{Ticker 6})} \\ &= ((\$1.001 * \$10000 + \$1.002 * \$8000)) / (\$10000 + \$8000) \\ &= \$1.00144 / \text{USDT}\end{aligned}$$

We then convert the stablecoin ticker (Ticker 1) to its USD price and volume:

$$\begin{aligned}\text{USD_PRICE}_{\text{Ticker 1}} &= \text{PRICE}_{\text{Ticker 1}} * \text{USD_ONRAMP_INDEX}_{\text{USDT}} \\ &= 28000\text{USDT} * \$1.00144 / \text{USDT} \\ &= \$28040.32\end{aligned}$$

$$\begin{aligned}\text{USD_VOLUME}_{\text{Ticker 1}} &= \text{VOLUME}_{\text{Ticker 1}} * \text{USD_ONRAMP_INDEX}_{\text{USDT}} \\ &= 25000\text{USDT} * \$1.00144 / \text{USDT} \\ &= \$25036\end{aligned}$$

Finally, the $BPI_{BTC/USD}$ is calculated based on all the BTC tickers in the set:

$$\begin{aligned}
 &BPI_{BTC/USD} \\
 &= VWAP_{(Ticker\ 1\ (converted\ to\ USD\ price\ and\ volume),\ Ticker\ 2,\ Ticker\ 3,\ Ticker\ 4\ (converted\ to\ USD\ price\ and\ volume))} \\
 &= \frac{SUM(PRICE * VOLUME)_{(Ticker\ 1,\ Ticker\ 2,\ Ticker\ 3,\ Ticker\ 4)}}{SUM(VOLUME)_{(Ticker\ 1,\ Ticker\ 2,\ Ticker\ 3,\ Ticker\ 4)}} \\
 &= \frac{(\$28040.32 * \$25036) + (\$28100 * \$20000) + (\$27900 * \$18000) + (\$28270 * \$11000)}{(\$25036 + \$20000 + \$18000 + \$11000)} \\
 &= \$28056.45 \text{ (rounded figure)}
 \end{aligned}$$

Once $BPI_{BTC/USD}$ is obtained, we can use it to derive the BPI for all other fiat currencies. For example,

$$\begin{aligned}
 &BPI_{BTC/GBP} \\
 &= BPI_{BTC/USD} * USD/GBP \text{ Exchange Rate} \\
 &= \$28056.45 * £0.78 / USD \\
 &= £21884.03 \text{ (rounded figure)}
 \end{aligned}$$

8.2 MAD Outlier Detection Example 1 (Ticker Set A under Condition A)

Consider Coin A with Ticker Set A as follows, where the coin fulfills Condition A, i.e. is listed on less than five exchanges::

Ticker 1 : 2.50, volume: 10000, exchange_A
 Ticker 2 : 1.20, volume: 30000, exchange_B
 Ticker 3 : 1.80, volume: 4000, exchange_C
 Ticker 4 : 1.10, volume: 5000, exchange_B
 Ticker 5 : 1.25, volume: 8000, exchange_D
 Ticker 6 : 1.28, volume: 9000, exchange_D

MEDIAN = volume-weighted_median^[ref]_{Ticker Set A} = 1.20
 MAD Constant = 1.4826

Absolute Deviation of each Ticker from (volume-weighted) MEDIAN,

$$\begin{aligned}
 &ABS_{Ticker_a} = |PRICE_{Ticker_a} - MEDIAN| \\
 &ABS_{Ticker_1} = |2.50 - 1.20| = 1.30 \\
 &ABS_{Ticker_2} = |1.20 - 1.20| = 0.00 \\
 &ABS_{Ticker_3} = |1.80 - 1.20| = 0.60 \\
 &ABS_{Ticker_4} = |1.10 - 1.20| = 0.10 \\
 &ABS_{Ticker_5} = |1.25 - 1.20| = 0.05 \\
 &ABS_{Ticker_6} = |1.28 - 1.20| = 0.08 \\
 &\text{Hence } ABS_{Ticker\ Set\ A} = \{1.30, 0.00, 0.60, 0.10, 0.05, 0.08\}
 \end{aligned}$$

MAD = volume-weighted_median^[ref]($ABS_{Ticker\ Set\ A}, VOLUME_{Ticker\ Set\ A}$) = 0.05

MMAD = MAD * MAD Constant = 0.05 * 1.4826 = 0.07413 (this is more than the minimum MAD constant of 0.0018, so we can use the MMAD to calculate the bounds)

Standard_deviation = 4

LOWER_BOUND = MEDIAN - MMAD * Standard_deviation = 0.90348

UPPER_BOUND = MEDIAN + MMAD * Standard_deviation = 1.49652

Hence based on these limits, Ticker_1 (2.50), Ticker_3 (1.80) > UPPER_BOUND (1.49652) and will be removed from the ticker set before the final price aggregation.

8.3 MAD Outlier Detection Example 2 (Ticker Set B under Condition B)

Consider Coin B with Ticker Set B as follows, where the coin fulfills Condition B, i.e. is listed on five or more exchanges:

Ticker 1 : 2.50

Ticker 2 : 0.83

Ticker 3 : 0.78

Ticker 4 : 0.77

Ticker 5 : 0.7643

Ticker 6 : 0.76

Ticker 7 : 0.7592

MEDIAN = unweighted_median_{Ticker Set B} = 0.77

MAD Constant = 1.4826

Absolute Deviation of each Ticker from MEDIAN, $ABS_{\text{Ticker}_b} = |PRICE_{\text{Ticker}_b} - MEDIAN|$

$ABS_{\text{Ticker 1}} = |2.50 - 0.77| = 1.73$

$ABS_{\text{Ticker 2}} = |0.83 - 0.77| = 0.06$

$ABS_{\text{Ticker 3}} = |0.78 - 0.77| = 0.01$

$ABS_{\text{Ticker 4}} = |0.77 - 0.77| = 0.00$

$ABS_{\text{Ticker 5}} = |0.7643 - 0.77| = 0.01$

$ABS_{\text{Ticker 6}} = |0.76 - 0.77| = 0.01$

$ABS_{\text{Ticker 7}} = |0.7592 - 0.77| = 0.01$

Hence $ABS_{\text{Ticker Set B}} = \{1.73, 0.06, 0.01, 0.00, 0.01, 0.01, 0.01\}$

Median ABS Deviation (MAD) = median($ABS_{\text{Ticker Set B}}$) = 0.01

Modified MAD (MMAD) = MAD * MAD Constant = 0.01 * 1.4826 = 0.014826 (this is more than the minimum MAD constant of 0.0018, so we can use the MMAD to calculate the bounds)

STANDARD_DEVIATION = 4

LOWER_BOUND = MEDIAN - MMAD * STANDARD_DEVIATION = 0.710696

$UPPER_BOUND = MEDIAN + MMAD * STANDARD_DEVIATION = 0.829304$

Hence based on these limits, Ticker_1 (2.50), Ticker_2 (0.83) > UPPER_BOUND (0.829304) and will be removed from the ticker set before the final price aggregation.

9 Appendices

List of BPI and USD_ONRAMP_INDEX exchanges and pairs.

Appendix A: BPI Exchanges & Tickers (BTC/<all CG-supported fiat currencies where available>, BTC/USDT, BTC/USDC tickers)

Exchanges	BPI Tickers
Binance	BTC/USDT, BTC/USDC, BTC/EUR
OKX	BTC/USDT, BTC/USDC
Coinbase	BTC/USD, BTC/USDT, BTC/EUR
Kraken	BTC/USD, BTC/USDT, BTC/USDC, BTC/EUR
Crypto.com	BTC/USD, BTC/USDT, BTC/EUR
Bitfinex	BTC/USD, BTC/USDT, BTC/EUR
Bitstamp	BTC/USD, BTC/USDT, BTC/EUR
Gemini	BTC/USD, BTC/USDT, BTC/EUR
Huobi	BTC/USDT, BTC/USDC

Appendix B: USD_ONRAMP_INDEX_{USDT} Exchanges & Tickers

Exchanges	USD_ONRAMP_INDEX _{USDT} Tickers
Coinbase	USDT/USD
Kraken	USDT/USD
Crypto.com	USDT/USD
Bitstamp	USDT/USD
Gemini	USDT/USD

Appendix C: USD_ONRAMP_INDEX_{USDC} Exchanges & Tickers

Exchanges	USD_ONRAMP_INDEX _{USDC} Tickers
Kraken	USDC/USD
Bitstamp	USDC/USD
Gemini	USDC/USD

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