TEKTELIC GEOLOCATION FAQ'S

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Q: Which gateway variants support geolocation?

A: TEKTELIC's KONA Mega gateways and geolocation-enabled KONA Macro gateways support geolocation. The KONA Macro gateway has another variant (with a different product code) that does not support geolocation.

Q: I have purchased a KONA Mega gateway or a geolocation-enabled KONA Macro gateway. Is there a cost for enabling the geolocation feature?

A: There is no extra cost for enabling the geolocation feature (i.e., no per-packet or per-device fee). However, a Maintenance and Support (M&S) agreement must be purchased and maintained for all geolocation enabled hardware to ensure software and firmware is always kept current. In some cases, depending on the conditions under which the gateway is purchased, stopping the M&S payments may result in disabling the fine timestamp generator engine (a.k.a. location engine) on the gateway.

Q: What does the geolocation feature on the gateway provide?

A: It calculates fine timestamps with nanoseconds resolution for all UL LoRaWAN® packets on a best-effort basis and sends the fine timestamp data along with other relevant metadata to the geolocation server, network server, or any other user defined destination.

Q: Is the calculated fine timestamp of a received UL packet sent up to the network server as part of the UL LoRaWAN® packet?

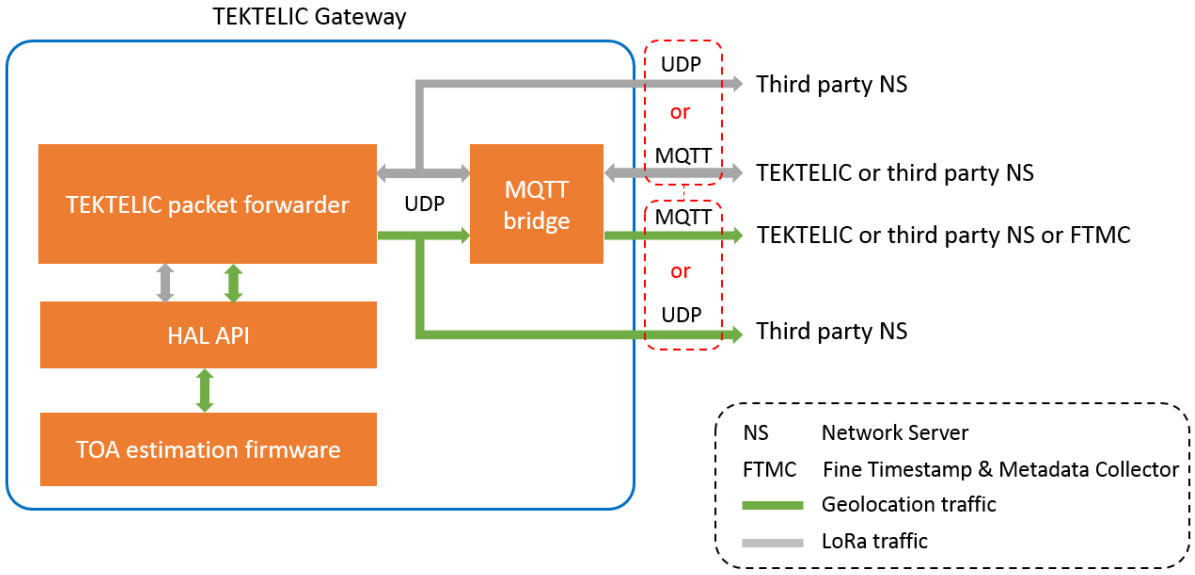
A: No, the calculated fine timestamp of a received UL packet and other relevant metadata are sent out (to a user defined destination) in a separate packet called a "TOA packet" (also called a "location packet") shortly after the LoRaWAN® packet is sent out to the network server. This guarantees that the UL LoRaWAN® packets are not delayed by the signal processing delay associated with fine timestamp calculation.

Q: How are the TOA packets generated on the gateway and sent out?

A: The fine timestamps are calculated by the TOA estimation firmware (a.k.a., location engine) on the gateway. A location API in the hardware abstraction layer (HAL) provides a set of functions for extracting the fine timestamp data from the location engine. Depending on the application, the packet forwarder (TEKTELIC or third party) or TEKTELIC timestamp forwarder receives the fine timestamp data from the HAL (through the location API) and forwards them to the desired destination. The following cases are possible depending on whether TEKTELIC or a third party packet forwarder is running on the gateway and, if a third party packet forwarder is running, whether it has been integrated with the location API or not.

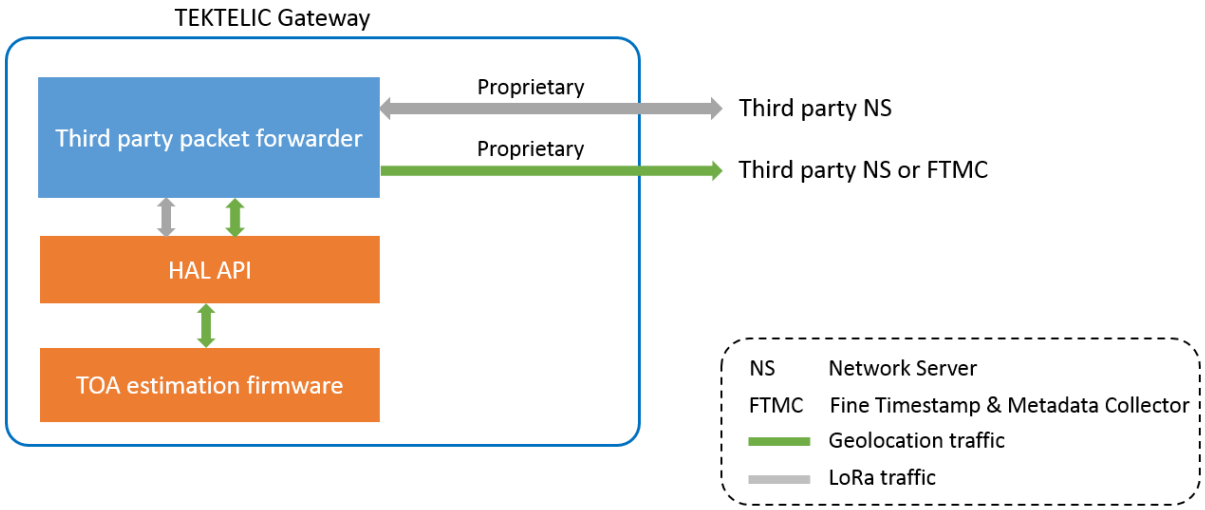
Case 1: TEKTELIC packet forwarder handles both the LoRaWAN® and the geolocation traffic. The two traffic planes are carried over the same protocol which can be either UDP or MQTT (can be configured by the user). If the UDP protocol is chosen, the LoRaWAN® and the geolocation traffic will be both routed to the network server (i.e., it is not possible to route the geolocation traffic to a different destination if UDP is used).

Gateway SW/FW lineup – Case 1

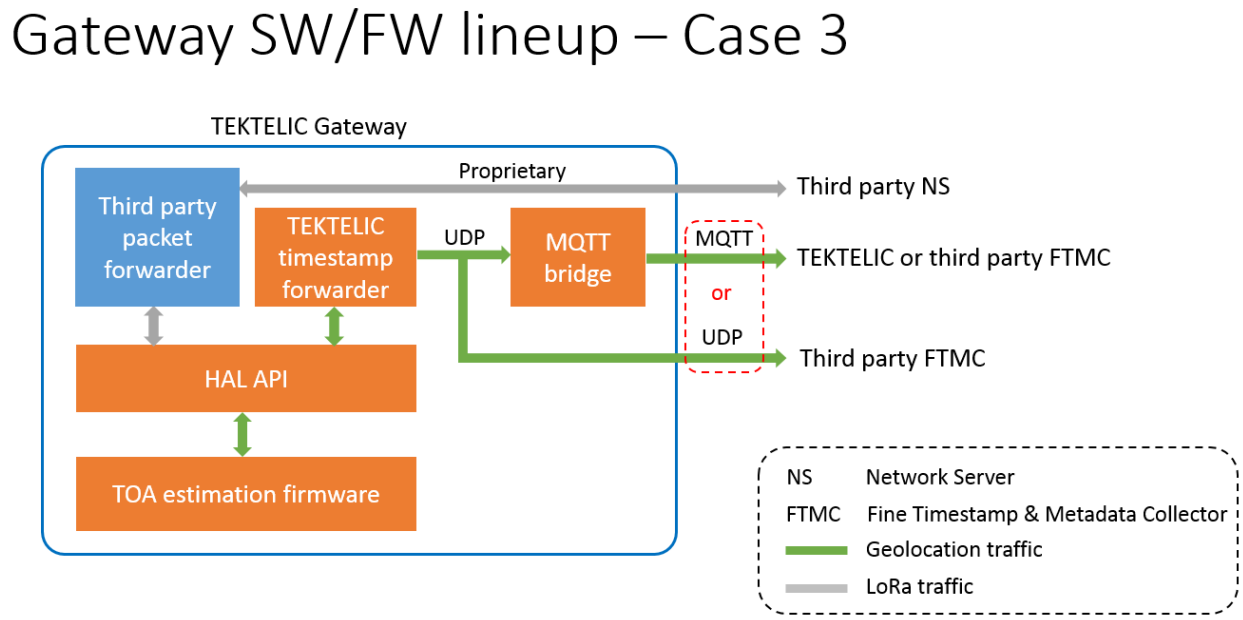


Case 2: A third party packet forwarder that has been integrated with the geolocation API (of the HAL) handles both the LoRaWAN® and the geolocation traffic over a proprietary protocol.

Gateway SW/FW lineup – Case 2

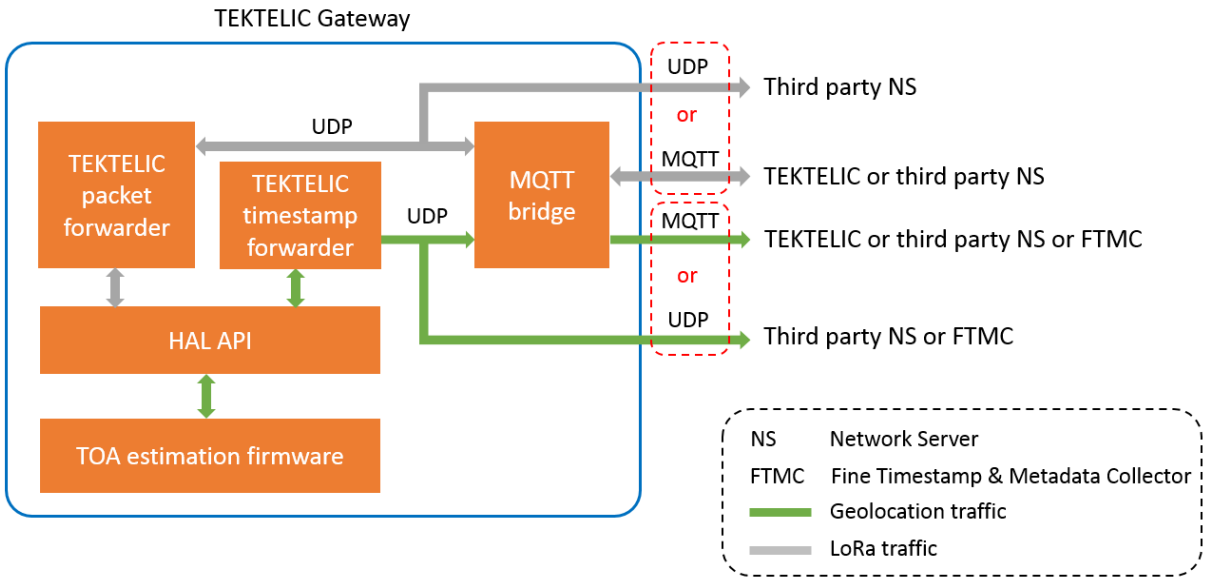


Case 3: A third party packet forwarder handles the LoRaWAN® traffic over a proprietary protocol. TEKTELIC timestamp forwarder handles the geolocation traffic which can be carried over either UDP or MQTT (as configured by the user).



Case 4: TEKTELIC packet forwarder handles the LoRaWAN® traffic which can be carried over UDP or MQTT. TEKTELIC timestamp forwarder handles the geolocation traffic which can be carried over UDP or MQTT. The choice of UDP versus MQTT can be independently configured for the LoRaWAN® and the geolocation traffic (i.e., they are not tied together as in Case 1).

Gateway SW/FW lineup – Case 4



Q: What is the format of the TEKTELIC TOA packets?

A: The TOA packets generated by TEKTELIC packet forwarder and TEKTELIC timestamp forwarder are JSON strings with the following format:

```
{
   "locpk":[
    {
        "mote": "DevAddr of the end-device",
        "frame_cnt": UL frame count,
        "freq_hz": channel frequency in Hz,
        "bandwidth": bandwidth in Hz,
        "sf": spreading factor,
        "antenna": antenna id,
        "toa_sec": the seconds portion of TOA in GPS epoch format,
        "toa_nsec": the nanoseconds portion of the TOA,
        "rssi_dbm": rssi in dBm,
        "snr_db": snr in dB,
```

```
        "fo_hz": estimated frequency offset in Hz,
        "toa_u_nsec": uncertainty of the TOA estimate in nanoseconds,
        "fo_u_hz": uncertainty of the frequency offset estimate in Hz,
        "lat": antenna latitude [-90,90] (North +, South-),
        "lon": antenna longitude [-180,180] (East+, West-),
        "alt": antenna altitude,
        "gateway_id": "gateway id",
        "mic": message integrity code
    }
]
}
```

More fields may be added to the above structure in the future. The location API running in the HAL provides the above information to the packet forwarder. A third party packet forwarder may choose a different format for the TOA packets.

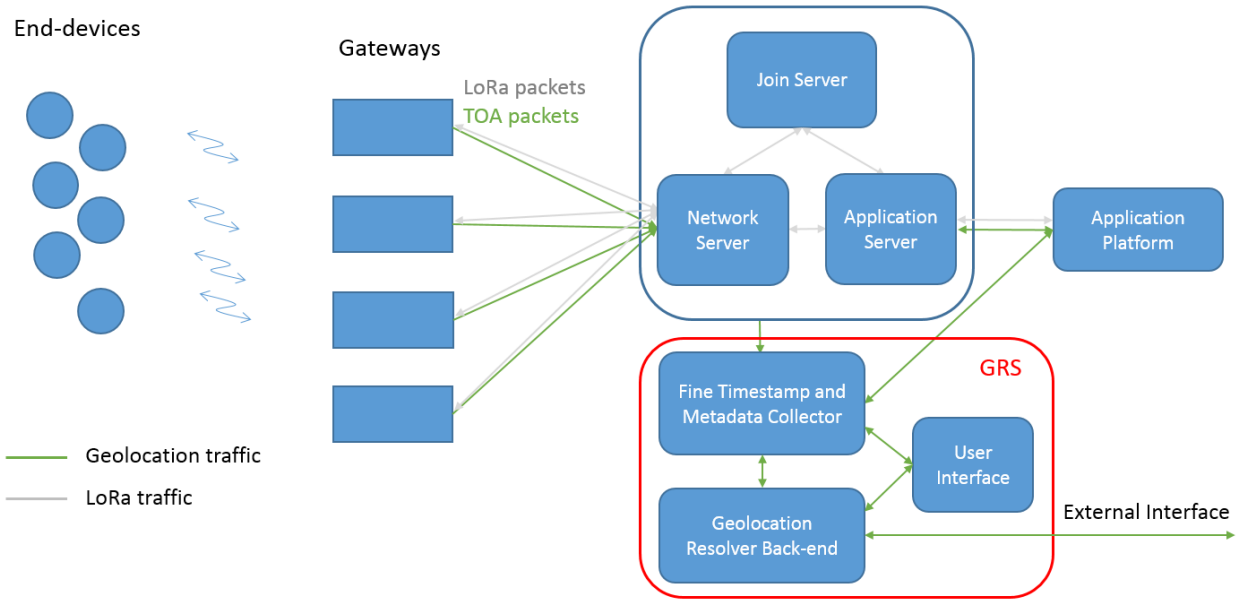
Q: Is there any other way to extract the TOA packets from the gateways?

A: A copy of all TOA packets generated by TEKTELIC packet forwarder and/or TEKTELIC timestamp forwarder is saved in the gateway log (this is a circular log that will wrap around after it reaches its maximum size). The user can pull these logs by establishing an SSH connection to the gateway, filtering the contents of the gateway log using the "locpk" keyword, and saving the filtered logs into a text file on the gateway. These files can then be pulled from the gateways and, after some parsing, they can be fed to a resolver engine (such as TEKTELIC geolocation resolver back-end) to get the location estimates.

Q: How are the TOA packets collected and used by the geolocation resolving server?

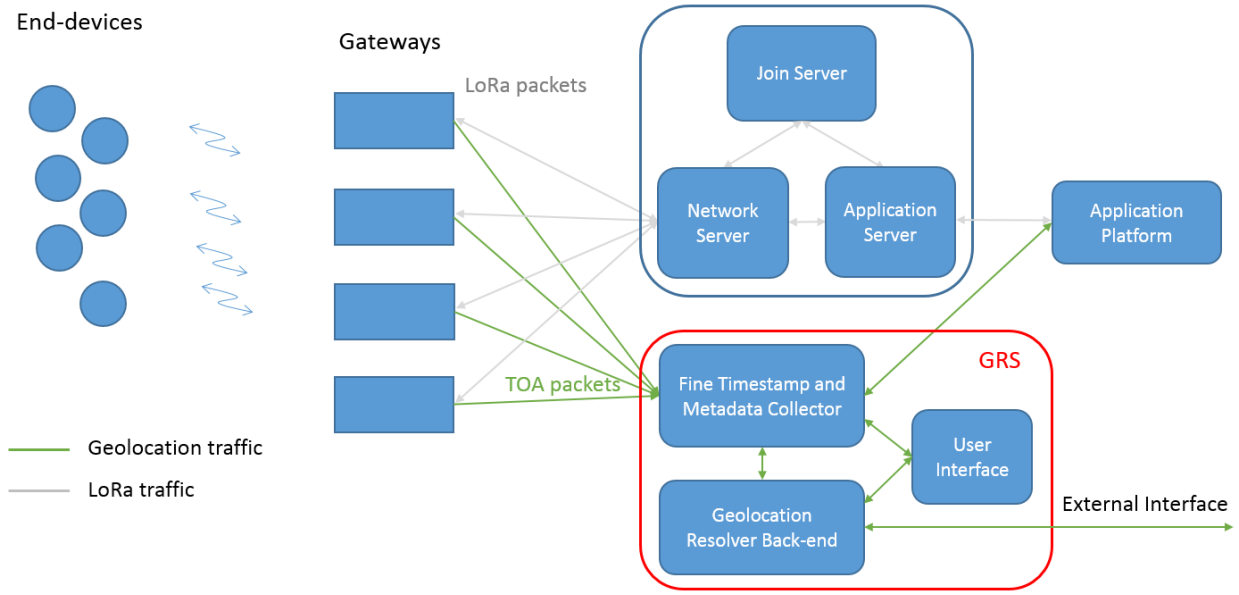
A: Two architectures are supported. In the first architecture, coined the network server dependent (NSD) architecture, the TOA packets are collected and passed to the geolocation resolving server (GRS) through the network server, as shown in the block diagram below.

Network server dependent architecture



In order to support scenarios where a customer is using a network server that has not been integrated with TEKTELIC TOA packets, we provide a network server independent (NSI) architecture as well. In this architecture, which is shown below, the TOA packets are directly sent to the GRS.

Network server independent architecture



Q: What are the main components of TEKTELIC geolocation server?

A: The main component of the resolver are

- Fine timestamp and metadata collector (FTMC)
- Geolocation resolver back-end (GR back-end)
- User interface (UI)

FTMC tasks:

- Collects the TOA packets either through the network server (in the NS dependent architecture) or directly from the gateways (in the NS independent architecture)
- Receives (sends) geolocation requests (responses) from (to) an application
- Upon receiving a geolocation request, retrieves the relevant TOA packets from its database and feeds to the GR back-end. It then generates a geolocation response using the results of the GR back-end and sends the response back to the application.

GR back-end tasks:

- Receives TOA packets from the FTMC or from another entity through its external interface. The TOA packets may belong to a single UL frame or multiple UL frames.
- Runs the geolocation algorithm and finds one or more location estimates.
- Returns the location estimates and some other data (statistics and accuracy measures) to the caller (i.e., the FTMC or an external caller).

UI tasks:

- Allows the user to configure and interact with the FTMC and the GR back-end.

Q: Do I have to use the fine timestamp and metadata collector (FTMC) if I want to use TEKTELIC's resolver?

A: No, you don't have to. You can directly use TEKTELIC geolocation resolver back-end if you have another way of collecting the fine timestamps and handling the geolocation

requests and responses (e.g., the network server and application server can implement the FTMC tasks)

Q: How can I use the TEKTELIC geolocation resolver back-end?

A: The TEKTELIC GR back-end is deployed on the cloud and can be accessed through its external interface using the GR back-end APIs. Two APIs are available: RESTful over HTTP and MQTT. The API documentations are available upon request.