Accurate time distribution using Cellular radio signal

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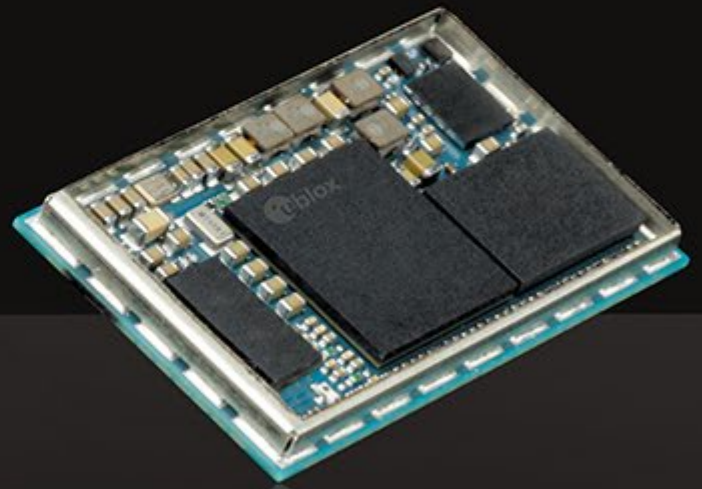


summary

objectives

overview

GNSS and cellular timing solutions

u-blox experience with LTECatM /NB-IoT

conclusions

Wireless timing solutions

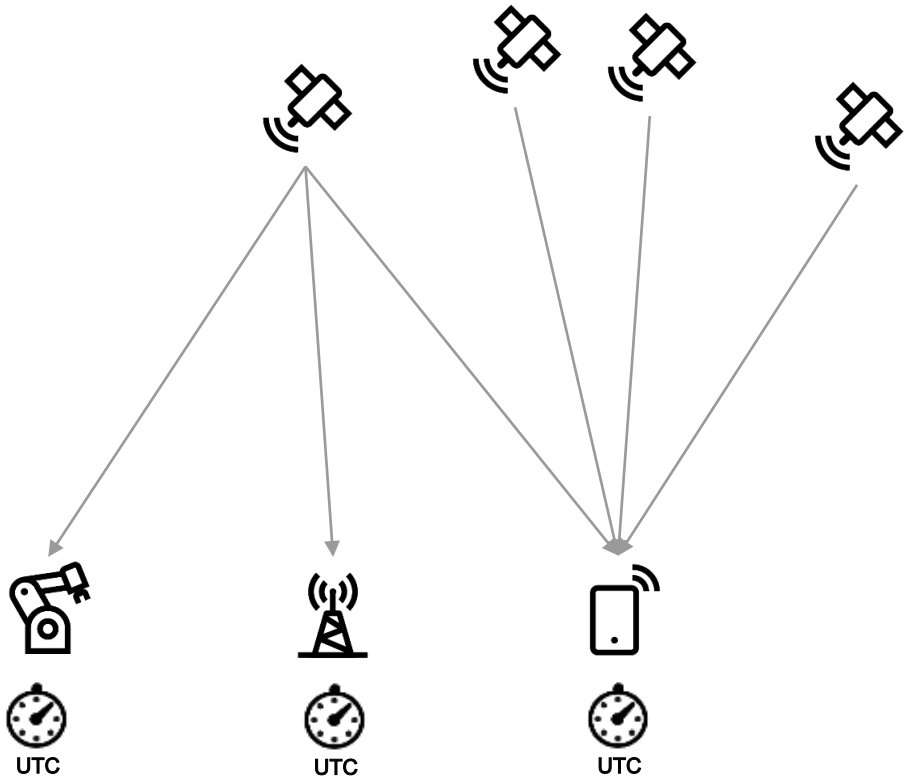
GNSS/cellular

- Objectives
  - **Report on u -blox experience in implementing a timing feature based on cellular (LTE CatM/NB IoT) radio signal reception**
    - Comparison with GNSS and 5G solutions / Complementary solution for outdoor/indoor scenarios
- Background
  - All **wireless** timing solutions require an infrastructure
  - **GNSS**
    - Uses satellite infrastructure (Atomic clocks in known orbits)
    - GNSS receivers use signal + navigation data to compute the offset of their clocks wrt UTC time
  - **Cellular**
    - Cellular modems are frequency synchronized with serving cellular BSs
    - An origin in the Radio signal frame structure can be defined (to phase synchronize independent cellular modems)
    - The possibility of time -stamping (UTC) the radio frames allows to distribute accurate UTC time.
      - Enabled by: Cellular provider or by Reference devices aligned with UTC time

Wireless timing solutions

GNSS

- Accuracy
  - 5-30ns
- Strengths
  - Receivers can work in a standalone mode
  - No extra infrastructure is needed
  - Timing mode: if the location of the GNSS receiver is known, a single satellite is enough to derive accurate UTC time
- A limitation is given by the poor Indoor penetration
  - GNSS and cellular timing complement each other



Wireless timing solutions

Cellular

- Cellular time and frequency distribution is based on the **existing cellular infrastructure**
  - Designed and configured to privilege **coverage** : good indoor penetration
  - Cellular infrastructure has **synchronization requirements** between base stations to avoid interferences

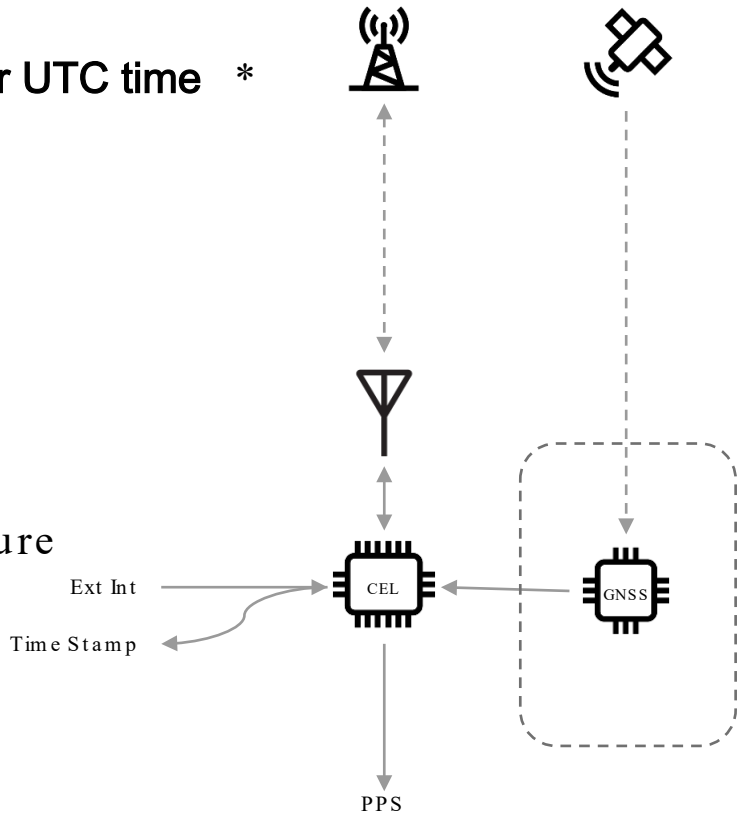
- **5G**:
  - Time information
    - **SIB-9** contains (optional) **referenceTimeInfo** (referenceSFN /time/ timeInfoType /uncertainty) field with absolute time info (10ns granularity). Alternatively, a RRC message is used.
    - Frame structure is aligned to UTC. If the device knows when the frame structure is expected to start, it can derive the absolute timing
  - **Requirements for E2E time distribution is 900ns**

- **Signal of opportunity** approach
  - Each LTE/5G radio signal can be used to frequency and phase synchronize arrays of cellular modems under the coverage area of the same Base Station

u-blox implementation

Signal of opportunity approach

- CEL modem functionalities have been extended with **timing capabilities**
  - Cellular modems are frequency synchronized with the serving BS
  - u-blox has added the possibility to **phase align** the internal clock to **local or UTC time** *
    - LTE frame is used to define a **local time reference**
    - Propagation delay is compensated using TA information
  - If cellular modem is combined with a GNSS receiver:
    - **GNSS is used as primary timing source** (CEL used for hold over)
    - It allows to align the modem clock to UTC
  - Two **GPIO pins + AT interface** are used to provide time distribution info
  - AT commands have been defined to enable and configure the timing feature
- Time distribution is be provided via:
  - **Pulse Per Second** (PPS aligned with local time or UTC*)
  - **Time -stamping** events (local time or UTC*)



* Absolute time can be given by a GNSS receiver or by a reference modem aligned with UTC time
TA: Timing Advance

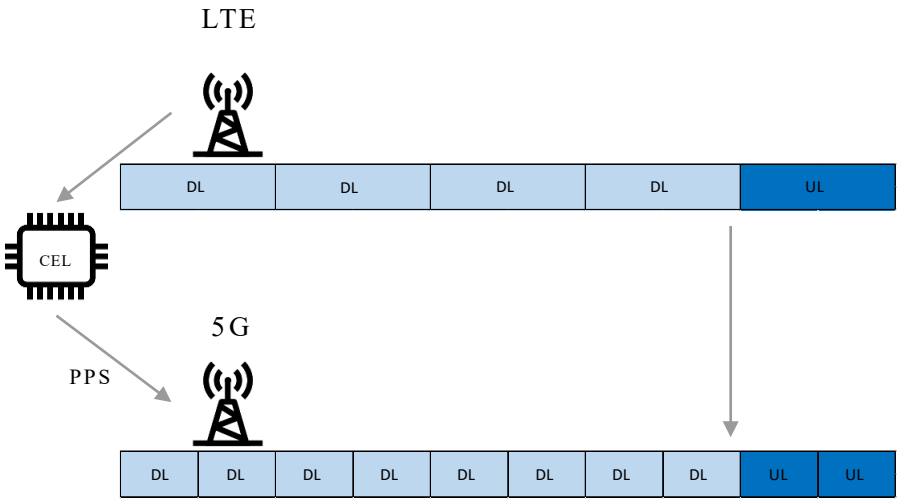
Using Cellular radio signal for synch

Use case: slot frame coordination

- Time synchronization plays a critical role in network configurations

- LTE/5G -NR **slot frame coordination**
  - In u-blox implementation, a reference timing signal is derived from the LTE-CatM/NB-IoT radio signal
  - The PPS generated by cellular modem can be used to time-synchronize a 5G-NR BS
    - This allows to avoid interferences between UL/DL phases of LTE and 5G-NR BSs

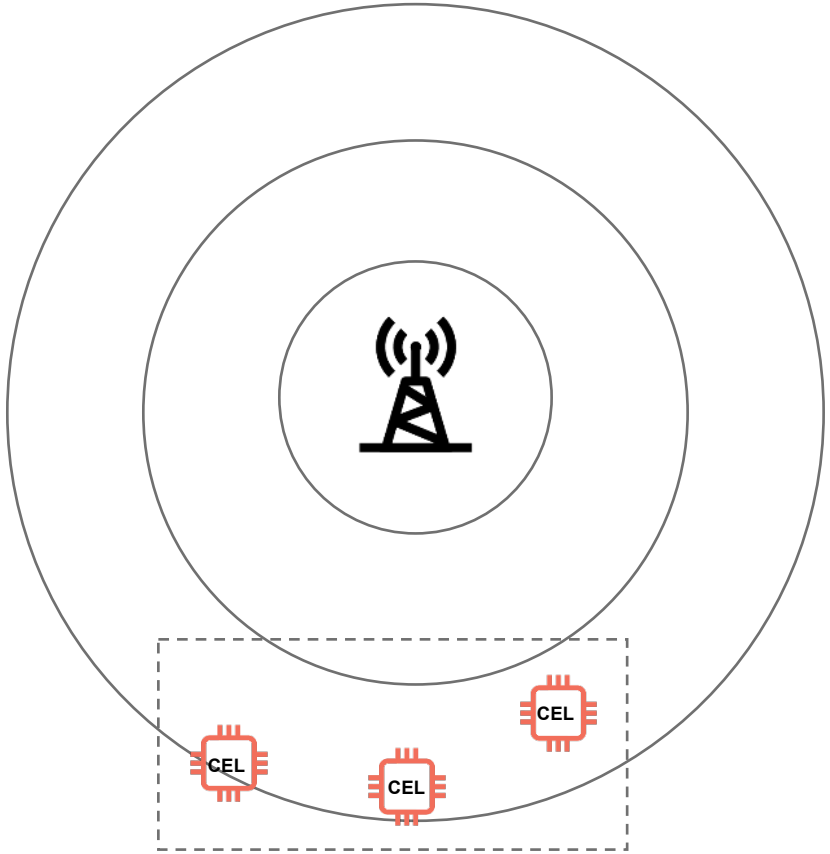
- Cellular modem operates in **standalone** mode
  - UTC time is not needed
  - The time of flight of the signal is compensated by using the Timing Advance information from the BaseStation
  - No SIM card is required



Using Cellular radio signal for synch

Use case: deep indoor device synchronizations

- **BS station frame timing**
  - All modems are camped to the same BS and use BS radio signal to synchronize
  - Allow **accurate realive timing** without the need of having GNSS
  - The signal from the serving cell is used to define a local time reference
  - Using LTE signal: Accuracy < 1us
    - Mainly due to the granularity of the Timing Advance information used for propagation delay compensation (~500ns)

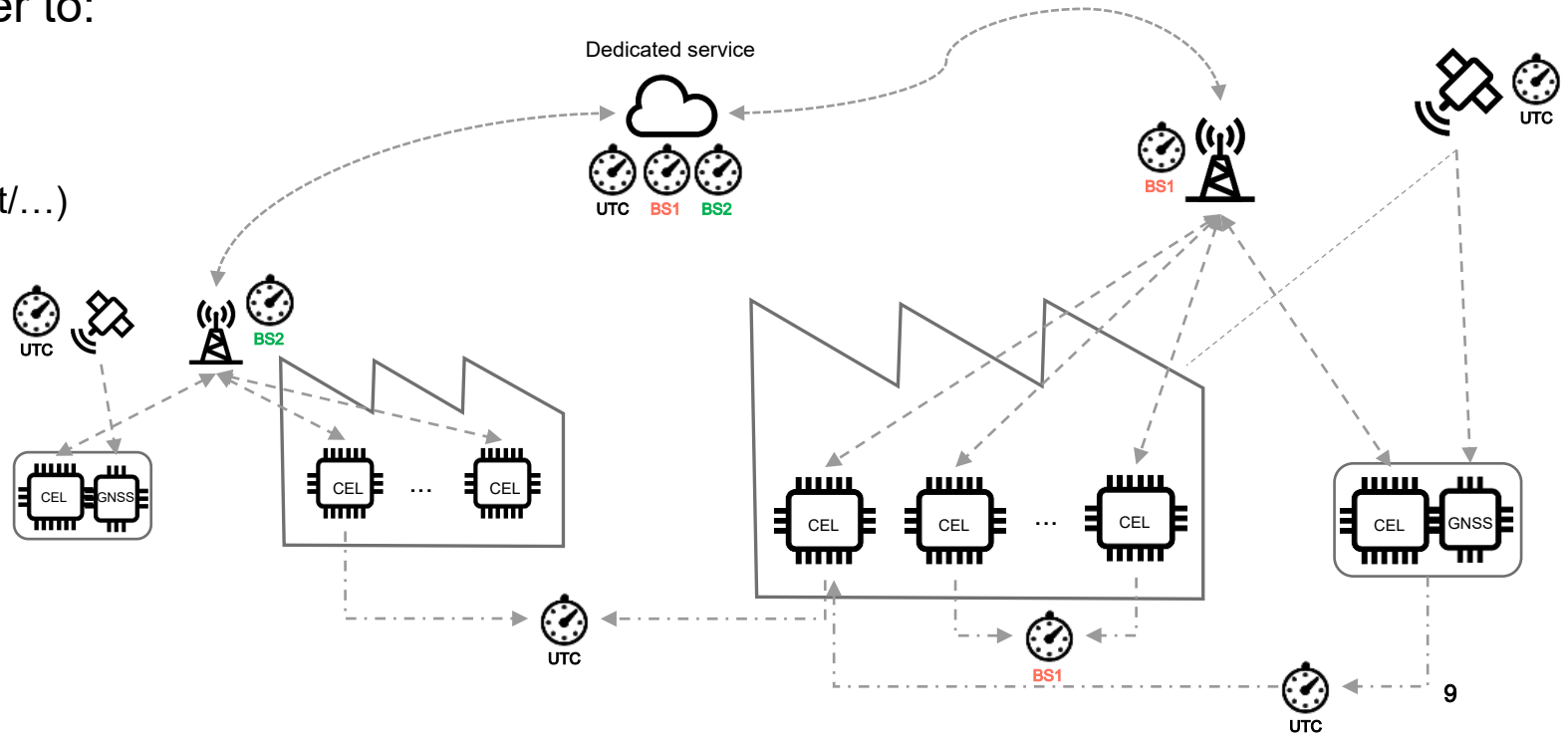


Using Cellular radio signal for synch

Use case: UTC time distribution

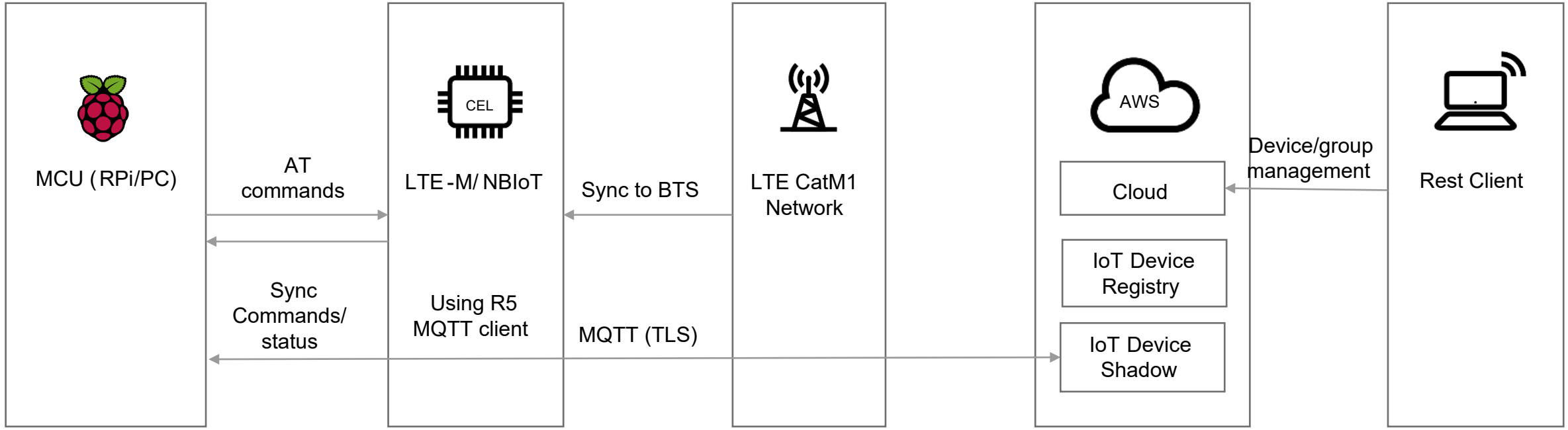
A **dedicated service** (APIs accessible via MQTT protocol) :

- Handles groups of devices (share UTC -local time offset between devices in the group/…)
- Allows **propagation of UTC time indoor**
- Allows to **synchronize** devices under the visibility of different BSs
- User Interface (UI) allows customer to:
  - Create groups of devices
  - Monitor the status of the devices
  - Trigger actions (sync/PPS/Ext -Int/…)



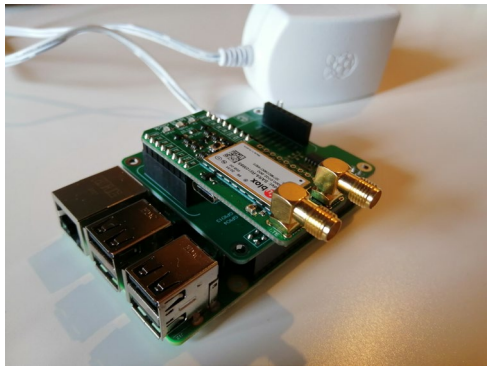
UTC time distribution

Service implementation



- Sets up the module and the MQTT connection to the cloud.
- Waits for incoming messages and periodically submits status.

- When asked synchronizes its internal clock to the BTS signal and provides PPS/EXTINT.



- Status is maintained in a device shadow (AWS IoT)
- Registry of devices and their groups managed using a REST API provided by API Gateway+Lambda .
- Lambda maintains the synchronization updating the shadows and reacting to IoT Rule actions.

- Authenticates to the REST API using apikey .
- Register and manages devices using the API.
- Can request the synchronization of all devices belonging to the same group.

Using Cellular radio signal for synch

Conclusions

- In u-blox implementation, independent cellular modems are time synchronized using BS radio signal and can provide time information using PPS/ Ext_int GPIOs and messages on AT interface

- In LTECatM /NBIoT the accuracy is <1us
  - Same approach can be used for 5G signal with expected better accuracy (finer granularity of TA info, down to 32ns)

- Devices with visibility of different BSs can be synchronized
  - Using UTC: reference devices with GNSS visibility and a dedicated service are needed
  - Relying on BS relative synchronization. The relative time error between BSs adds to the error budget
    - 5G: defined in 3GPP TS 38.104 (OTA time alignment error)

- GNSS and cellular timing complement each other
  - Outdorr /indoor scenario

Thank you
for your attention