Accurate Timing for IoT Applications, Everywhere

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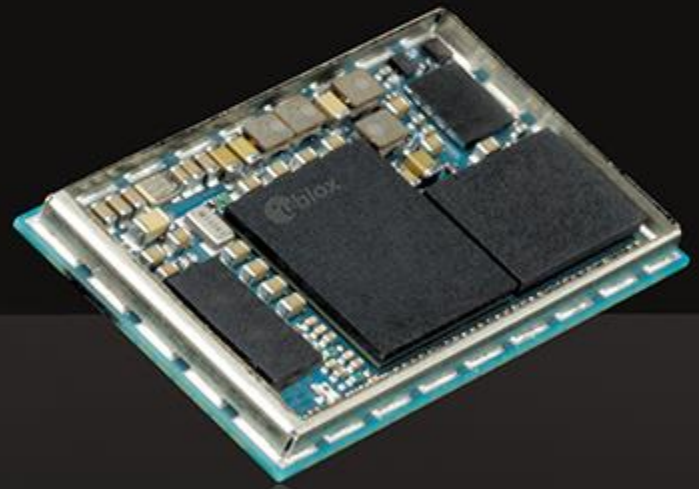


Cellular Synchronization

Summary

- Cellular wireless signals from Low Power Wide Area Networks have good indoor penetration
- A cellular modem could use such wireless signals for timing application, as well as for communications
- Cellular signals stability enables their usage for accurate time-keeping in IoT sensor networks

- We present a method that allows **wireless** distribution of precision timing indoors and undergroung **down to 1us**

Cellular Synchronization

Need for Synchronization

- An array of synchronized cellular modems allows to distribute time accurately between independent devices (sensors, actuators, measurement units, …) wireless
- Examples: industrial manufacturing, distributed databases, shared documents, stock trades, sensor fusion, multi-player games, indoor 5G-cells deployment,…

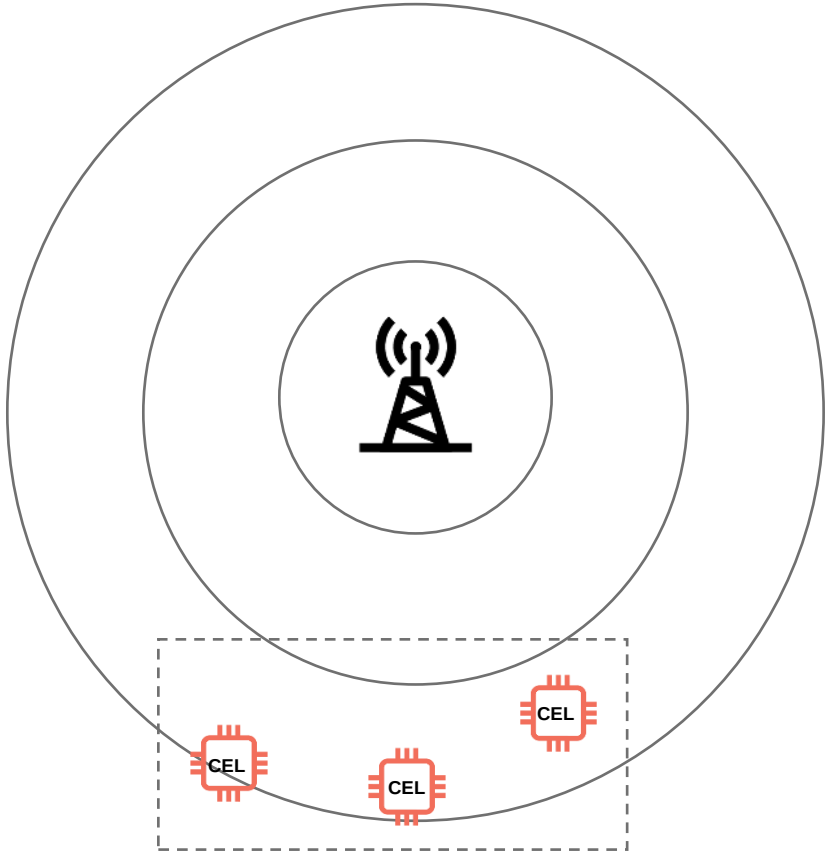
- Time distribution can be provided via:
  - Pulse Per Second (**PPS**)
    - Used for precise time keeping
  - **Time-stamping** events
    - Required if events occur “simultaneously” in separate equipment/locations
    - Ordering of events established by time-stamping using a common clock
    - requires end-point synchronization to this common clock

Cellular Synchronization

Basic principles

- Groups of devices connected to the same serving cell can be synchronized within **1µs**.
  - Can be done today using **LTE**
  - waiting for the complete implementation of 5G NR synchronization feature expected in Rel.16

- Using LTE physical layer signals such CRS to provide timing information to the application
  - Differences in the propagation time of flight between devices can be largely countered using TA information
- LTE frame is used to define a **local time reference**
  - Time origin: e.g at next wrap of Frame/Sub-frame number



CRS: Cell Reference Signal
TA: Time Advance

UTC vs Base station frame timing

Cellular Synchronization

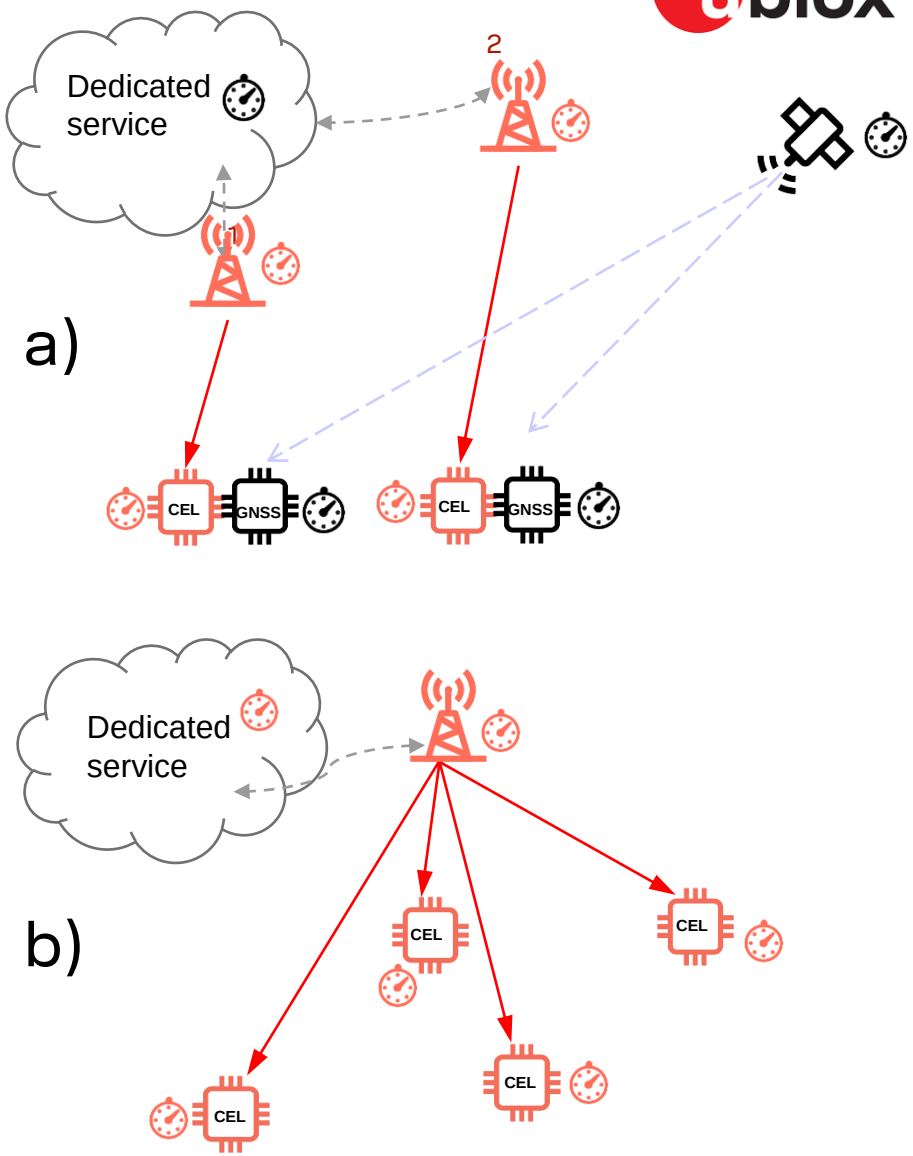
Arrays of Cellular modems can be syncronized using:

a)UTC time

- GNSS is used to initialize time to UTC.
  - Time is then propagated accurately using sync with BS (when GNSS not available)
- Needed if modems are far away and/or connected to different Serving cells

b)BS station frame timing

- All modems are camped to the same BS and use BS frame to synchronize
- Allow accurate relative timing without the need of having GNSS
- The signal from the serving cell is used to define a **local time reference**



Cellular base station | Modem | GNSS receiver | Local time | UTC time

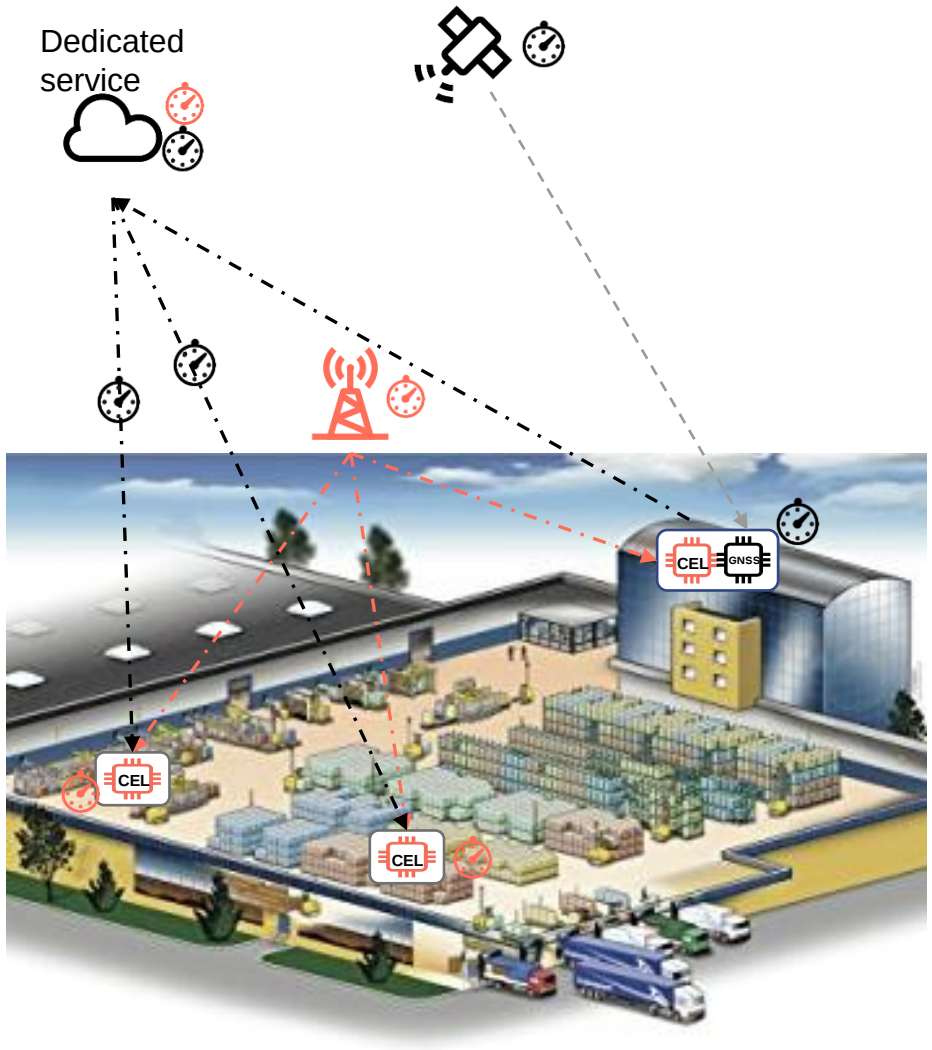
Cellular Synchronization

Implementation modem/server

A dedicated service allows the **synchronization of groups of devices** connected to the same BS (by using local or UTC time) or connected to different BSs, in multiple sites (by using UTC time)

Dedicated service:

- Allows propagation of UTC time indoor
  - Once the offset between local and UTC time is made available from a reference device
- Business logic and DB to handle groups of devices (share UTC time between devices in the group…)
- User Interface (UI) allows customer to:
  - Create groups of devices
  - Monitor the status of the devices
  - Trigger actions (sync/PPS/Ext-Int/…)

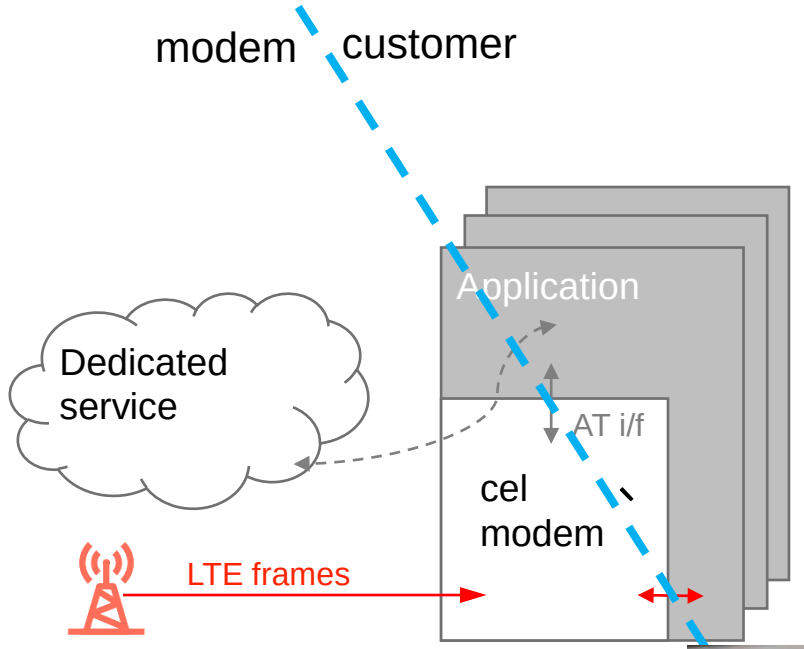


Cellular Synchronization

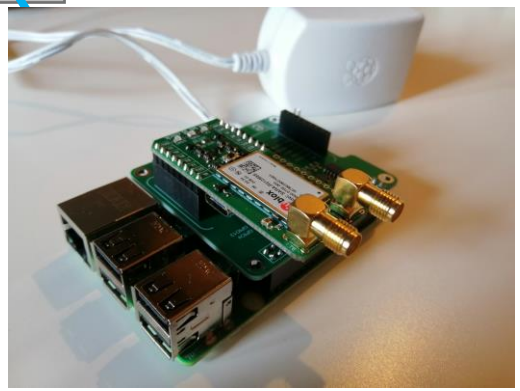
HW setup for the cellular timing platform

HW setup: CEL modem + host processor

- The CEL modem provides **hardware trigger** facilities to the application, which may be
  - time-stamping of an interrupt
  - a pulse per second (PPS) output stream
- Associated information over a conventional **AT interface** with the CEL modem, such as configuration/status information/time
- The application communicates with a dedicates service using CEL modem for connectivity
- Service+application inform the set of devices about their configuration



RPI3 + CatM cellular modem



Cellular base station | Modem | GNSS receiver | Local time | UTC time

Timing accuracy characterization

Cellular Synchronization

Relative time between two modems connected to the same BS is considered

1)Time stamp of external interrupts:

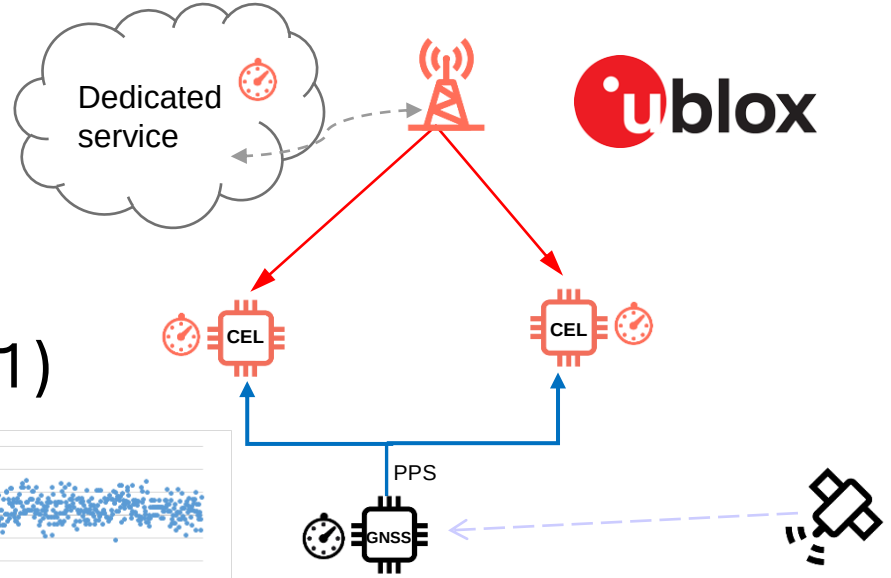
- The same reference PPS signal is sent from a GNSS to both devices
- Difference between independent timestamps from modems

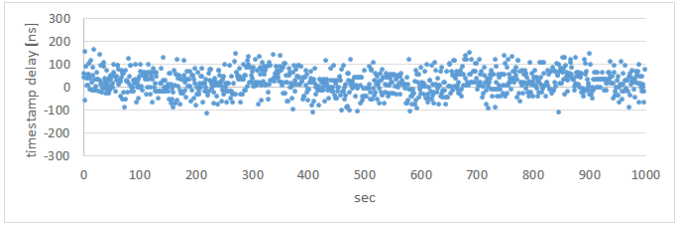
2)PPS

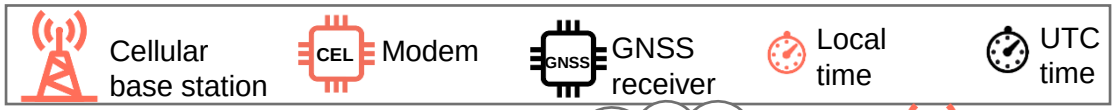
- Two CEL modem generate independently a PPS signal
- PPSs are compared with an oscilloscope

In our test setup, both characterization tests have shown timig accuracy **<1us**

1)







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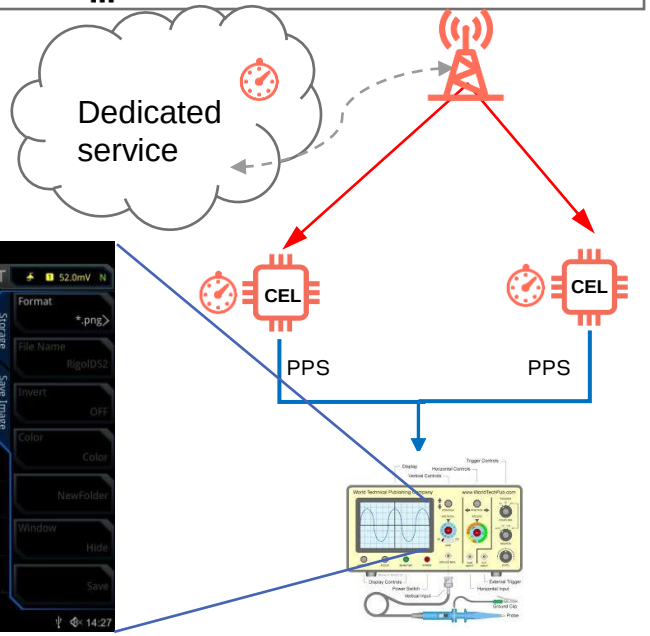
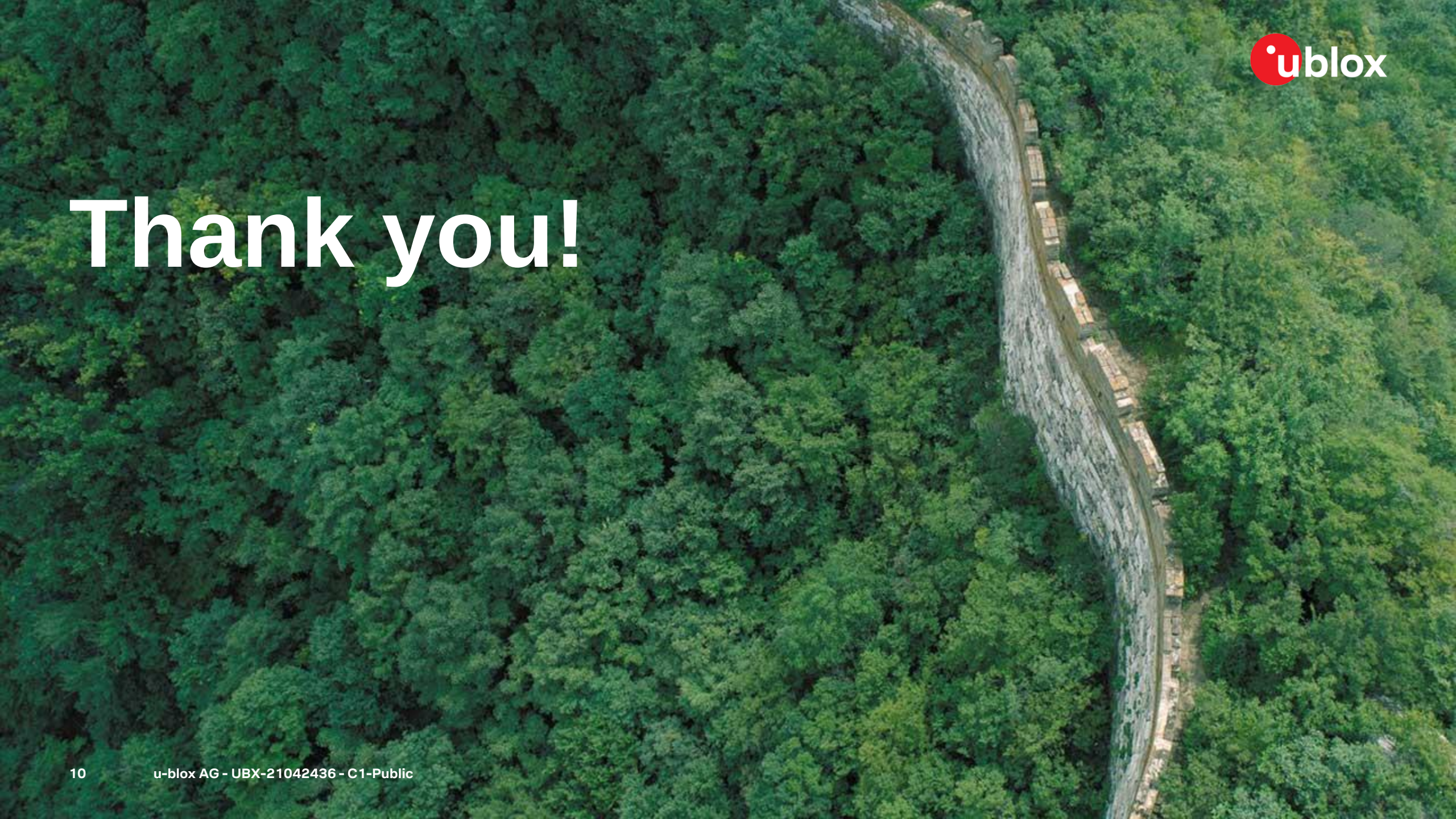


Cellular Synchronization

Conclusions

- We have implemented an **HW setup** and a **dedicated demo service** to validate and characterize an accurate time distribution based on the cellular wireless signal

- We have shown that arrays of independent cellular modems can be synchronized better than 1us using CatM/NB infrastructures


Thank you!