WHITEPAPER

GNSS timing and the rise of small cells

The importance of precision timing for small cells derived from GNSS satellites

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Executive Summary

Precision timing based on GNSS satellites is a low-cost, reliable, and ubiquitously available reference time derived from satellite-hosted atomic clocks. It can be easily implemented in Small Cell base stations as a primary, secondary, or backup precision timing solution. This whitepaper discusses the requirements and solutions for precision timing reference in Small Cell applications.

Fig. 1: The explosion of mobile data traffic in high-use areas is driving the adoption of Small Cells

The rise of Small Cells

The explosion of mobile data traffic is driving the adoption of Small Cells to efficiently relay traffic to and from end-devices in high-demand areas. Small cells are low-powered radio access nodes that operate in licensed and unlicensed spectrum having a range typically from 10 meters up to 1 or 2 kilometers, as compared to mobile macrocells which have a range of tens of kilometers.

Small Cells are typically used in urban environments such as multi-storey buildings, heavily used traffic routes, offices, hotels, schools, hospitals, events, airports and public transportation hubs.

In particular, small cells are a vital part of the business case for fourth generation networks. Small, inexpensive base stations supporting carrier-class WiFi, WiMAX and now LTE allow Operators to deliver the mass-market, video-rich, low-latency data services that enable new revenue streams from their customers.

Small Cell base-stations are deployed at street-level or within buildings in a variety of compact packaging styles. They support a variety of methods of connecting to the operators' core networks, including fiber, wireline, microwave or even LTE itself.

With so many applications competing for bandwidth, radio spectrum has become a precious resource. To make best use of this resource, Small Cell base stations implement:

- **Time-Division Multiplexing (TDM)** to separate transmit and receive data enabling the use of single-channel spectrum, and

- **Co-ordinated Multi-Point (CoMP)** transmission and reception among multiple base stations in dense cells to improve spectral efficiency.

Both of these technologies rely on very accurate synchronisation of signals broadcast from neighbouring base stations, typically within 1-3 microseconds. Small Cell base stations must therefore have access to an external, highly accurate and reliable reference clock to work. Access to several of these sources is typically required to ensure reliability in all possible deployment scenarios.

Fig. 2: GNSS satellite signals: accurate, cost-free and widely available

Achieving precision timing in Small Cell base stations

No single method of synchronization is universally applicable to all Small Cell installations. Some deployments gather time synchronisation from an over-laying macrocellular network, some can make use of a high-quality connection to the core network, and some can achieve synchronisation based on signals received from Global Navigation Satellite Systems (GNSS) such as GPS or GLONASS.

To insure reliable performance in different deployment scenarios without incurring unnecessary installation costs, a Small Cell design must support **two or more of these methods** automatically.

GNSS satellite signals: accurate, cost-free and widely available

Fig. 3: u-blox LEA-M8F time & frequency reference GNSS module
17.0 x 22.4 x 3.6 mm

Precision timing based on GNSS satellites is a low-cost, reliable, and ubiquitously available reference time derived from satellite-hosted atomic clocks. It can be easily implemented in Small Cell base stations as a primary, secondary, or backup precision timing solution.

u-blox time and frequency products provide multi-GNSS synchronization for cost-sensitive network edge equipment including Small Cell and Femto Cell wireless base stations. u-blox' LEA-M8F timing & reference frequency module is a fully self-contained phase and frequency reference based on GNSS, but can also be used as part of a complete timing sub-system including macro-sniff Synchronous Ethernet and packet timing.

The LEA-M8F surface-mount module includes a low-noise 30.72 MHz VCTCXO meeting the master reference requirements for LTE Small Cells and provides 100 ppb autonomous hold-over. An external TCXO or OCXO can also be measured and controlled for TD-LTE, LTE-Advanced and other applications requiring extended hold-over.

External sources of synchronization are supported through time-pulse and frequency inputs and a message interface. This allows measurements from macro-sniff, Sync-E or packet timing to be combined with measurements from GNSS.

u-blox LEA-M8F features

Model	Type							Supply		Interfaces				Features										
	GPS / QZSS	GLONASS	Galielo	BeiDou	Timing & Frequency	Dead Reckoning	Precise Point Positioning	3.0 – 3.6 V	Lowest power DC/DC	UART	USB	SPI	DDC (I²C compliant)	Programmable (Flash)	Data logging	Extra front-end LNA	Front-end SAW filter	RTC crystal	Internal oscillator	Antenna supply	Antenna short circuit detection / protection	Antenna open circuit detection pin	Timepulse output	External interrupt / Wakeup
LEA-M8F	•	•	R	•	•			•	•	•		o	•	•		•	•		V	•	P		•	•

V = VCTCXO
P = Short circuit protection only
o = Optional, not activated per default or requires external components
R = Galileo ready with future firmware

u-blox time and frequency products include timing integrity measures and alarms that report phase and frequency uncertainty both during normal operation and hold-over. They feature a high dynamic range radio with both analog and digital interference mitigation supporting their inclusion as an integral part of a local area base station design.

LEA-M8F example application: Small Cell

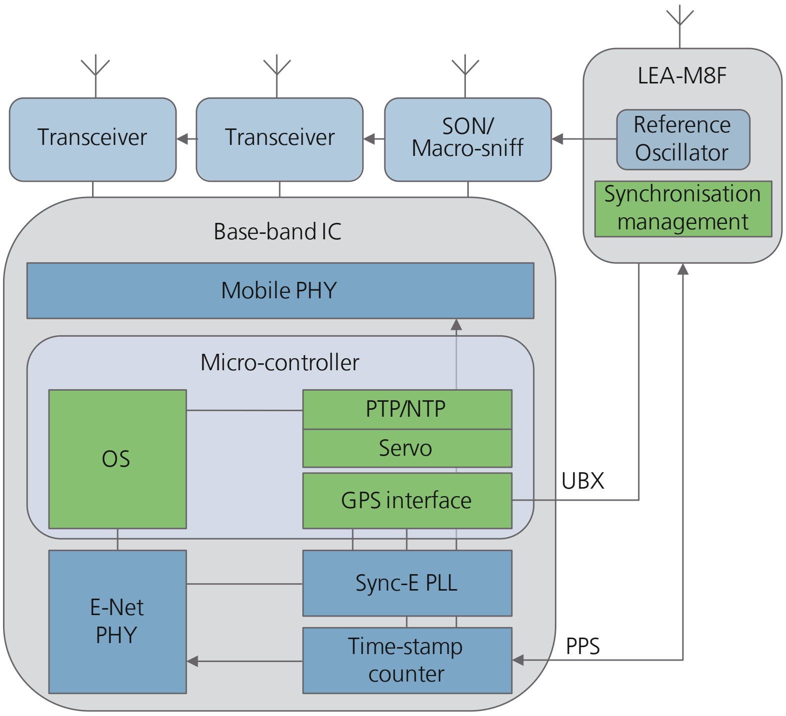

Fig. 4: u-blox LEA-M8F Small Cell application

In a wireless Small Cell application, the LEA-M8F can distribute a disciplined low-phase noise 30.72 MHz reference signal directly to the base station's RF transceivers.

GNSS synchronisation is combined with other timing sources by an exchange of synchronisation signals, status and control messages with the base-band processor. Source selection and hold-over may be controlled by either the LEA-M8F or the base-band application.

The LEA-M8F can track signals from satellites from any two constellations (e.g. GPS and GLONASS, GPS and BeiDou, GLONASS and BeiDou) simultaneously. Compatibility with GPS, GLONASS and BeiDou GNSS systems gives the LEA-M8F access to a constellation of more than 50 satellites, allowing synchronisation even in heavily populated urban or indoor areas with limited sky view.

For stationary applications, once a location is known, timing can be maintained with the signal from just a single satellite. Network aiding improves cold start sensitivity to better than -155 dBm, sufficient to ensure that the receiver can start in many indoor applications. Once started, the excellent tracking sensitivity (-167dBm) and single-satellite capability maintains continuous operation in all but the most challenging RF environments.

GPS, GLONASS and BeiDou operate at slightly different RF channel frequencies. This introduces the possibility of timing offsets introduced by different delays in antenna installations and filters, in addition to any offsets between the satellite systems themselves. The LEA-M8F automatically calibrates these offsets whenever sufficient satellite view from each constellation is available to provide the best continuity in phase regardless of the mix of satellites used at any given time.

The LEA-M8F also incorporates "Receiver Autonomous Integrity Monitoring" for timing applications (T-RAIM), using any signals in excess of the minimum to confirm the integrity of the synchronisation provided. This reduces the risk of erroneous synchronisation in the event of the failure of an individual satellite and intentional or unintentional interference. RAIM becomes possible as soon as signals from at least 5 satellites become visible at start-up (or in a mobile application) and at least 3 satellites in subsequent stationary operation.

LEA-M8F performance summary: synchronization

Frequency output:	30.72 MHz disciplined
Phase noise:	10 Hz: –90 dBc/Hz 100 Hz: –126 dBc/Hz 1 kHz: –140 dBc/Hz 10 kHz: –147 dBc/Hz 100 kHz: –153 dBc/Hz 1 MHz: –156 dBc/Hz
Jitter (100 Hz – 1 MHz):	0.15 ps
EVM (100 Hz - 1 MHz @ 2100 MHz):	< 0.2%
Frequency control: (internal oscillator)	GNSS locked: 5 ppb Hold-over: 100 ppb, 24 hr
Frequency control: (external oscillator)	Resolution: < 5 pp Frequencies: 19.2, 20, 26, 30.72 MHz Hold-over: determined by external oscillator
Phase control:	Clear sky: < 20 ns Indoor: < 500 ns typ.
Time-pulse input:	Resolution: < 50 ns
Time-pulse output:	Jitter: < 2 ns
Timing interfaces	1 timepulse output 2 timepulse/frequency inputs
Serial interfaces	SPI, UART and I^2C
Protocols	NMEA, UBX binary, RTCM
Supply voltage	3.0 V to 3.6 V

For samples of the LEA-M8F timing & reference frequency GNSS module and EVK-M8F evaluation kit details, contact u-blox.

About u-blox

Swiss-based u-blox (SIX:UBXN) is a global leader in positioning and wireless semiconductors for the consumer, industrial and automotive markets. Our solutions enable people, vehicles and machines to locate their exact position and wirelessly communicate via voice, text or video.

With a broad portfolio of chips, modules and software solutions, u-blox is uniquely positioned to enable OEMs to develop innovative personal, professional and M2M solutions quickly and cost-effectively. With headquarters in Thalwil, Switzerland, u-blox is globally present with offices in Europe, Asia and the USA. (www.u-blox.com)

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