Open Seminar Series

Geoscience & Remote Sensing

Accurate positioning, timing and relativistic geodesy through optical clocks and telecommunication networks

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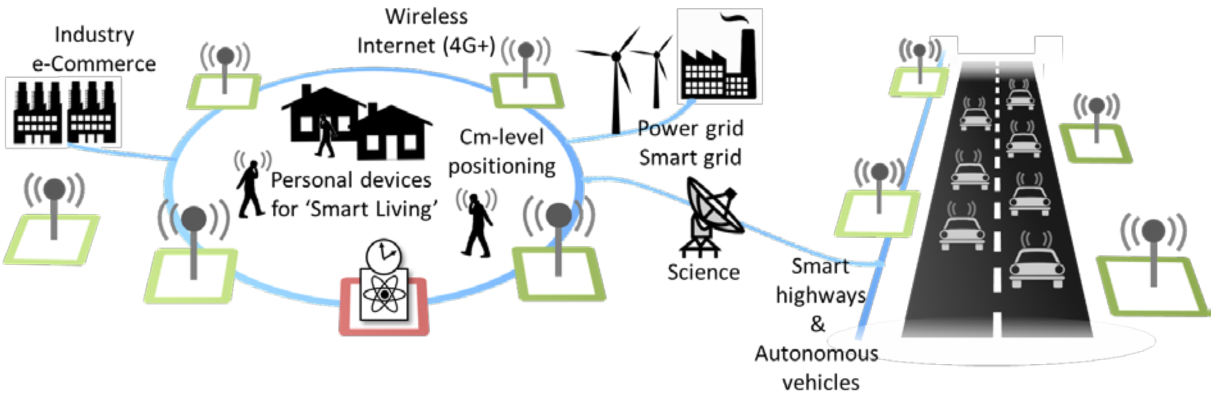
Global Navigation Satellite Systems (GNSS) such as GPS are well-known for positioning and navigation. The two enabling ingredients of GNSS are precisely synchronized atomic clocks, and the propagation of electromagnetic waves through spacetime as described by General Relativity. The former makes it possible for all GNSS satellites to act as synchronized beacons, emitting radio pulses at virtually the same time, while the latter allows Earth-bound GNSS receivers to compute the delays of the radio pulses and thereby their position relative to the GNSS satellites.

Traditional atomic clocks, such as those used in GNSS, are now being superseded by so-called optical clocks. Such clocks use ultrastable lasers and ultracold atoms to measure time with 18 digits precision. This implies that through the gravitational redshift, optical clocks may be used as 'Einstein sensors' of gravitational potential differences corresponding to height differences of about 1 cm.

For any clock application, be it time dissemination, navigation or relativistic geodesy, at least two clocks need to be compared and synchronized. For optical clocks, this can be achieved through telecommunications optical fiber. This technique may also be used with traditional atomic clocks, and can even lead to terrestrial positioning systems based on hybrid fiber-optic/wireless networks. This concept is currently explored by VU University and TU Delft in the 'SuperGPS' project, which aims at providing positioning with 10 cm uncertainty, for instance on a highway to enable self-driving vehicles.



Schematic view of a possible future SuperGPS network, and some of its applications. The SuperGPS network makes use of transceivers for wireless positioning (green squares), which are synchronized to an accurate atomic clock (red square) through fiber-optic telecommunication links (blue curves).