Distributed synchronization in wireless networks

O. Simeone[1], U. Spagnolini[2], Y. Bar-Ness[1] and S. H. Strogatz[3]

[1]Center for Wireless Communications and Signal Processing Research
New Jersey Institute of Technology
Newark, New Jersey 07102-1982, USA

[2]Dip. di Elettronica e Informazione, Politecnico di Milano
P.zza L. da Vinci, 32 I-20133 Milano (Italy)

[3]Department of Theoretical and Applied Mechanics,
Cornell University, 212 Kimball Hall, Ithaca, New York 14853-1503, USA

e-mail: osvaldo.simeone@njit.edu
(*) corresponding author

Abstract

A large number of applications in decentralized (sensor or ad hoc) wireless networks is enabled by, or benefit from, the availability of a common time-scale among the participating nodes. Examples range from tracking of moving objects via sensor networks to coordinated medium access control or cooperative transmission. Achieving and maintaining synchronization in such scenarios poses new challenges in terms of scalability and energy efficiency, and offers new opportunities through the interplay with specific distributed estimation/ detection applications. In this context, an interesting solution, which is currently being investigated, is provided by distributed synchronization schemes based on the exchange of local time information among neighboring nodes at the physical layer (e.g., via transmission of a train of common waveforms that follows the local clock).

This paper presents a survey of current research on distributed synchronization for decentralized wireless networks and illustrates the role of signal processing therein, with emphasis on physical layer-based synchronization schemes. The topic is introduced by tracing its origin in the parallel investigations carried out independently in mathematical biology and communication theory. Available models are discussed and compared. Open problems, such as trade-off complexity versus accuracy and fault-tolerance, are outlined and some solutions are provided using tools from signal processing and algebraic graph theory. Available analytical results are also reported, along with numerical examples that corroborate the main conclusions, lending evidence to some interesting phenomena, such as ”small-world” effects on distributed synchronization. The close relationship between distributed synchronization and distributed estimation/ detection applications is discussed as well, showing the synergy between these two problems. Finally, synchronization of non-periodic signals (chaos) is briefly touched upon for completeness and for its (debated) applicability to point-to-point wireless systems.