Foreword

Synchronization is the bedrock of the telecommunication highways. Much like the pavement of a highway, synchronization is often taken for granted, since it is effectively invisible when it is working. But it is an enabler of many aspects of the transfer of voice and data. Some services directly require synchronization. More specifically, synchronization can optimize the use of a given bandwidth, increasing available throughput in a fixed band.

Time-and-frequency issues are rich and complex enough that they form their own discipline. Unfortunately, there are few places of study that have this unique focus as an institute unto itself. Hence, the importance of this book. There is much confusion about principles of time and frequency, in part because our human experience of time is so intriguing. Time is a major focus in human culture, in art, philosophy, and song. Yet time in science, engineering and metrology is a different thing.

Scientific time and frequency start with a clock, a device that realizes a theoretical principle in a physical way. The underlying principle in any clock is always a law of physics that predicts circumstances in which the states of a system will repeat at a constant rate. A clock physically realizes this theoretical principle and produces this rate, or frequency, with some level of accuracy and stability. The underlying principle is a theory of physics that forces the theoretical rate of the clock to be constant by definition. Time from a clock comes by counting the states as they repeat themselves, just as counting days produces the calendar. Hence, a clock fundamentally produces a frequency, with time optionally produced by using a counter. The standard frequency is a physical quantity, equivalent to an energy. The time standard, however, is a man-made artifact. A standard frequency signal can be produced by a single device, a cesium standard. To get standard time from a clock, as opposed to time intervals, the clock must first be set, or synchronized, against a reference. Then, since the clock is at best a frequency device with some white noise on the signal, any two clocks will wander off from each other in time without bounds if they are not re-synchronized periodically, whereas the best clocks may be bounded in their native frequency differences.

So where does the time reference come from? Metrologically, the practical time standard is a weighted average of clock times from all over the world. This is produced by the International Bureau of Weights and Measures (Bureau International des Poids et Mesures – BIPM) in the forms of International Atomic Time (TAI) and Universal Coordinated Time (UTC). These time scales are produced only after the fact. Any real-time time signal can be only a prediction of what the correct time will be when it is defined later.

The result of these facts is that a system that requires only frequency can have a stand-alone device that produces the signal. But a system that requires time must compare the count of time on its local device to an external reference. This has broad implications in telecommunications systems, and in the many other systems that require some level of accurate time coordination. Not only must clocks be chosen and implemented to run properly, but their signals must be transported and measured properly.

This book describes the needs for synchronization in telecommunications networks and the current evolution of methods and standards that enable it. The challenge of supplying needed synchronization to telecommunications systems is primarily an engineering problem, not a theoretical or scientific one. Because the requisite frequency devices can be expensive, and because the necessary time synchronization must be transported, there is a need for a synchronization network. The requirements of a communications network fundamentally conflict with those of a synchronization network. The communications network ideally separates functional layers, so devices interact with other devices only one layer up or down. Synchronization requires direct access to the lowest layer, the physical layer, since synchronization, unlike data, requires a physical signal. Applications that are required to consume some form of synchronization signal can be in any layer of the communications network. Hence they must break or tunnel through the isolation of layers to get access to the synchronization signal, in violation of the layer principles of a communications network.

Alternatively, a synchronization signal can be supplied from a source external to the communications network. Receivers of Global Navigation Satellite Systems (GNSS) such as the U.S. Global Positioning System (GPS) are commonly used to provide both time and frequency synchronization. These cannot be used everywhere, however, both because of expense and because of difficulties in getting the synchronization signals where they are needed. In addition, GNSS signals are vulnerable to interference – both intentional and unintentional interference. Thus, even with GNSS signals available, a synchronization network remains essential.

As I write in 2013, synchronization in communication systems is in the midst of evolving from the role of primarily frequency synchronization to the role of precise time synchronization. The metrology community separates these two types of synchronization by calling "synchronization" in frequency the name "syntonization", though the telecommunications community uses the word synchronization for both. The transport of networks in the late 80 s and 90 s was itself synchronous in frequency, or syntonous. With the advent of packet networks, the transport no longer needed syntonization, yet many applications and services still required various forms of either syntonization or synchronization or both.

Among other things, synchronization optimizes available bandwidth, enabling a more efficient use of the spectrum. Today, wireless networking is becoming more ubiquitous. Time synchronization is becoming essential to allow high data rates in the limited wireless spectrum. This becomes a complex engineering problem, as many different scenarios require different types of synchronization. Traditional synchronous networks still remain in use and require syntonization, while packet networks dominate all new roll-outs. Further, many size-scales of wireless networks are being deployed, from macro-cells over cities to femto-cells in a small interior of a building. These hybrid networks challenge operators to supply needed synchronization to all the requisite applications and services.

Within the context of these circumstances, this book is timely. As synchronization becomes both more complex and more necessary, there still remains a dearth of training and learning options. This book is a comprehensive effort by experts who have been developing standards and engineering devices, and employing these in real networks. It should help fill the void for those trying to negotiate the diverse and complex world of time and frequency issues in communications systems.

This book is a collaboration of major figures in the creation and use of synchronization. I will not repeat the information in the biographic, but I want to mention my appreciation and respect for this team of authors and the current effort. The authors are a mixture of standards experts, equipment building and testing experts, and operators who must implement and maintain synchronization. This book is a work of significant magnitude, involving many hours of development and coordination.

Synchronization in telecommunications is a fascinating field. It involves complex concepts and difficult engineering efforts. Concomitantly, the field creates great benefits for many users, facilitating an increasing ease for human social communications underpinned by large data transfers. In addition, synchronization facilitates large industries representing many billions of dollars. This book can take the user a long way along this river. Enjoy!

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