sensor networks in their pure form, though a vibrant research field [24], [25], are therefore not widely used in automation practice.

Such was the situation until about one or two years ago. Industrial communications was a mixture of fieldbus systems, Ethernet-based approaches, and some wireless solutions [26], [27], all of them struggling with the legacy of four decades of history in a market with life cycles of plants that are in the range of decades. The recent adoption of IoT and CPS concepts in the automation world, however, changes the scenery again. They put the old and still valid quest for integration of information flows in automation into a wider context [28]. The idea that everything in automation is connected and, e.g., that individual products or workpieces are parts of this ecosystem is not new, it was introduced with agent-based distributed manufacturing systems years ago [29]. Nevertheless, recent advances in communication technology allow interconnection on a wider and more fine-grained scale [30]. On the application side of the automation pyramid, the other big trend is to move the business logic into cloud-based applications [7], [8]. This is in line with IT trends and has much to do with new business models of software solution providers on the one hand and the wish to make IT-related costs smaller and more predictable on the customers' side.

The big difference with respect to the previous waves of evolution in industrial communication is that the technological driving force is consumer electronics. So far, the predominant roots of industrial communication were instrumentation and IT. This seems to change. The work on Ethernet TSN originated in the standardization of audio video bridging (AVB) [31]. In addition, the interest of the telecom industry stems from extending their business as mobile Internet providers, which draws from developments in consumer electronics [3]. After all, one of the appealing features of the IoT concept is the promise to use everyday Internet-enabled devices like smartphones or

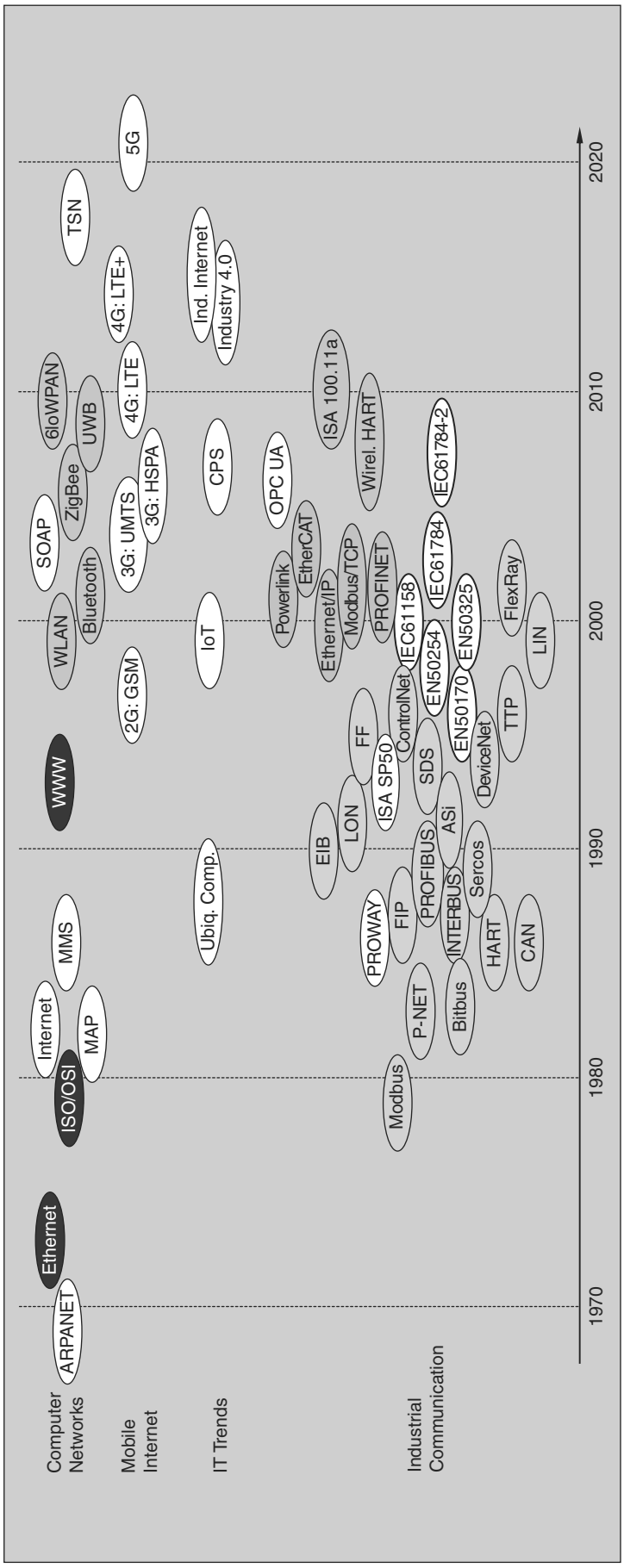

FIGURE 1 – The milestones in the evolution of industrial communication and related technology fields. 2G: second generation; 3G: third generation; 4G: fourth generation; ARPANET: Advanced Research Projects Agency Network; GSM: global system for mobile communication; ISO: International Organization for Standardization; LTE: long-term evolution; WLAN: wireless local area network; WWW: World Wide Web; ASI: actuator/sensor interface; EIB: European installation bus; CAN: controller area network; PROFIBUS: process field bus; FIP: factory instrumentation protocol; HART: highway addressable remote transducer; HSPA: high-speed packet access; LIN: local interconnect network; LON: local operating network; MAP: manufacturing automation protocol; MMS: manufacturing messaging specification; PROWAY: process data highway; SOAP: simple object access protocol; TCP: transport control protocol; TTP: trime triggered protocol; UMTS: universal mobile telecommunications system; UWB: ultrawide band; SDS: smart distributed system; PROFINET: process field net; EtherCAT: Ethernet for control automation technology.