Part I

Introduction

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Short-range communications systems characterize a wide range of scenarios, technologies and requirements. There is no formal definition of such systems though one can always classify short-range systems according to their typical reach or coverage. We define short-range communications as the systems providing wireless connectivity within a local sphere of interaction. Such a space corresponds to the first three levels of the multisphere model as discussed in the Book of Visions of the Wireless World Research Forum (WWRF) [1]. Figure 1.1 depicts the multisphere concept, highlighting the levels associated with short-range communications, namely Personal Area Network, Immediate Environment and Instant Partners [2–4]. Short-range systems involve transfer of information from millimeters to a few hundreds of meters. However, short-range communication systems are not only systems providing wireless connectivity in the immediate proximity, but in a broader perspectivethey also define technologies used to build service access in local areas. The WWRF envisions that by year 2017 there would be seven trillion wireless devices serving seven billion people. Certainly, the overwhelming majority of these devices will be short-range communication systems providing wireless connectivity to humans and machines.

Together with wide/metropolitan area cellular systems, short-range systems represent the two main developing directions in today's wireless communications scene. In terms of design rules and target capabilities, short-range systems have certain commonalities as well as marked differences from their counterparts, cellular systems. Maximizing the supported data throughput is quite often one of the main design targets for both types of wireless networks though a detailed comparison between them is not straightforward. Figure 1.2 shows the evolution of data rate support in cellular, metropolitan, Wireless Local Area Networks (WLAN) and very short-range systems. We can see that a steady increase in the supported throughput at a rate of approximately one order of magnitude every five years [5].

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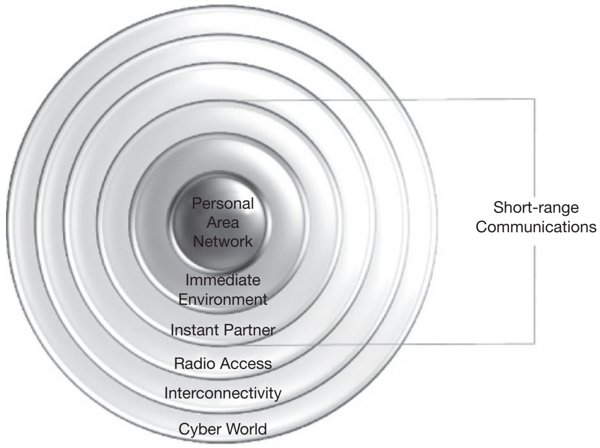

Figure 1.1 Short-range communications within the WWRF multisphere reference model.

There is a great deal of synergy between short-range and cellular networks, and in many cases exploiting their complementary characteristics results in very efficient solutions. The most important approaches to short-range are depicted in Figure 1.3, where a classification according to the operating range is shown. The short-range systems include Near Field Communications (NFC) for very close connectivity (range in the order of millimeters to centimeters), Radio Frequency Identification (RFID) ranging from centimeters up to a few hundred meters, Wireless Body Area Networks (WBAN) providing wireless access in the close vicinity of a person, a few meters typically, Wireless Personal Area Networks (WPAN) serving users in their surroundings of up to ten meters or so, Wireless Local Area Networks, the *de facto* local connectivity for indoor scenarios covering typically up to a hundred meters around the access point, Car-to-car communications (or Vehicle Area Networks) involving distances of up to several hundred meters and Wireless Sensor Networks, reaching even further.

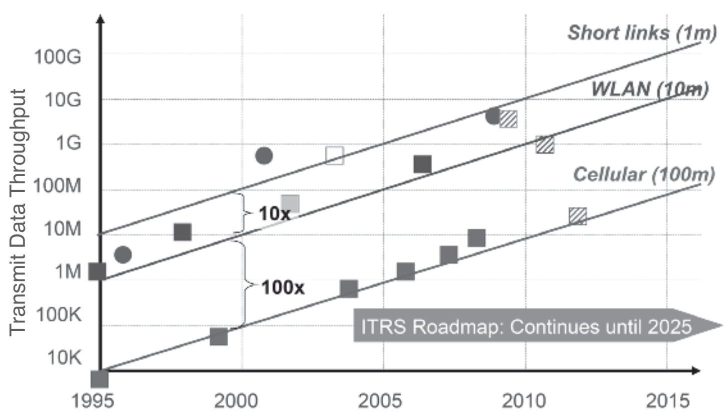

Figure 1.2 Data throughput evolution if mainstream communication systems [Courtesy of Wigwam project].

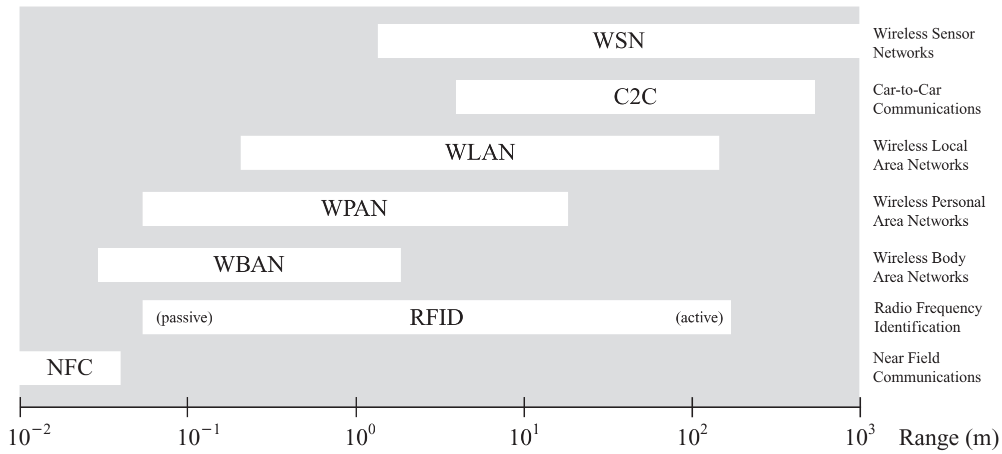

Figure 1.3 Short-range communications systems and their typical operating ranges.

Each of the aforementioned short-range approaches involves in general one or more specific air interface technologies (i.e. physical layer and medium access control layer) typically with the corresponding supporting standards defining most of the relevant technical details. A vast amount of literature exists for short-range technologies, in particular WLAN, WPAN, RFID and WSN are by far the most visible representative approaches. Ever since their inception, Wireless Local Area Networks (WLAN) and Wireless Personal Area Networks (WPAN) have had a leading role in the development and further diversification of short-range communications systems. Initial developments targeted simple point-to-point communication systems working as cable-replacements to connect wireless devices (e.g., computers, peripherals, appliances, etc.) Currently, there are several active and evolving standards particularly focused on short-range systems. The IEEE 802.11 standard series is the most popular example of coordinated and sustained development in short-range communications, particularly focused on WLAN. As for WPAN, the IEEE 802.15 series defines a family of wireless networking standards with different technologies, such as Bluetooth (802.15.1), High Speed (802.15.3) and Sensor Networks (802.15.4). There are several different physical layer descriptions in each of the 802.15 sections, for example 802.15.4a for UWB based wireless sensor networks or 802.15.3c Gigabit communication networks.

Figure 1.4 shows other aspects of short-range communication systems, highlighting the great diversity in possible air interface solutions, topologies as well as achievable data throughput and supported mobility. Physical layer technologies range from conventional radio (e.g., narrowband) to Ultra Wide Band (UWB) systems, exploiting single and multicarrier modulation schemes. Typical frequency bands span from some MHz to millimeter-wave systems (60 GHz and beyond). Moreover, optical communications are also attractive short-range technologies, including infrared and visible light communications. In general, short-range networks have *ad hoc* distributed architectures allowing direct and multi-hop connectivity among nodes. Centralized access is also possible, as in WLAN, which in fact supports both centralized and distributed topologies. Even though short-range systems are typically conceived for fixed or low-mobility environments, as in essentially all the indoor applications, new scenarios even foresee cases where high mobility is involved. Examples include car communications where

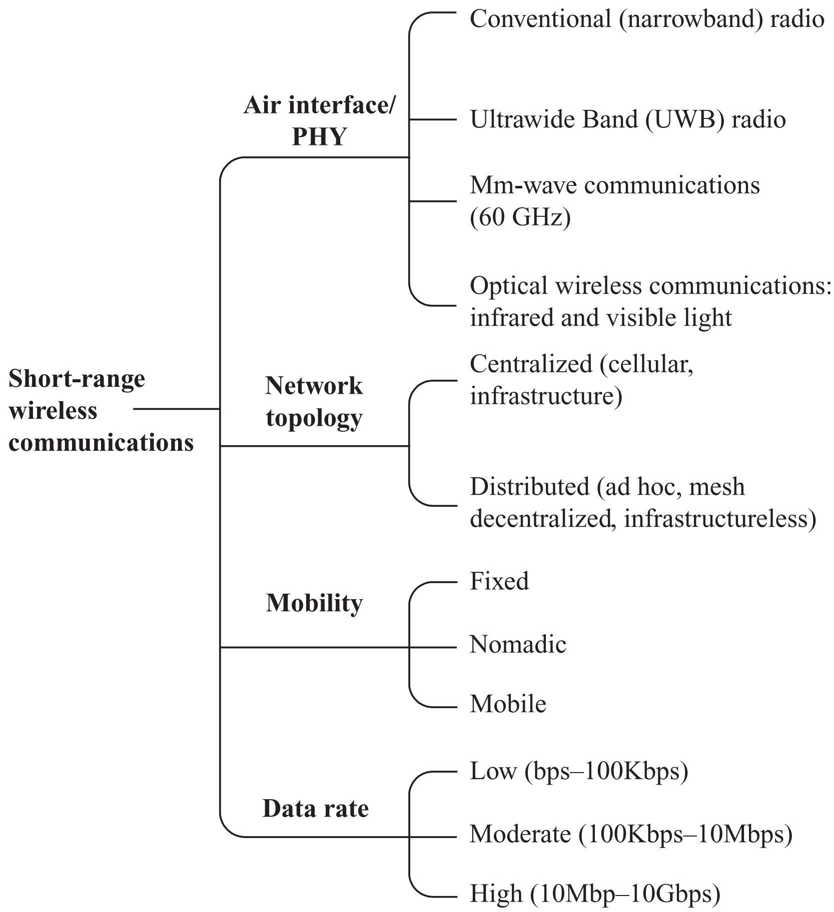

Figure 1.4 A general classification of short-range communications.

cars traveling in opposite directions attempt to exchange information, or information retrieval in the case of car-to-roadside communications. Data throughput requirements for short-range systems are also very broad, from some hundred bits per second in simple RFID systems up to 10 Gbps and beyond in WLAN systems, for instance.

In many cases low power consumption is one of the key requirements for short-range systems, particularly taking into account that transceivers are in many cases battery-driven. Particular attention is necessary when designing short-range devices while minimizing the power consumption at the three basic conditions of the transceiver, namely transmitting, receiving and idle states. Low cost is another important factor to take into consideration when designing short-range systems. Furthermore, minimizing size and weight are also quite often imperative engineering principles that need to be applied by the designer of such communication systems.

Another important aspect of short-range communications networks is their relationship to other existing wireless networks and their possible interaction. In very many scenarios it is indeed convenient to consider short-range networks as complementary to cellular networks, instead of the conventional approach considering the former in complete isolation from the rest of the networks. Countless efforts have been put into the research and development of *ad hoc* networks in the last twenty years. However, their presence today is effectively eclipsed by the omnipresent cellular network. It can be argued that one of the reasons for such a weak penetration is precisely the fact that these networks were designed largely ignoring the other mainstream network approach and their possible cooperation. As a matter of fact, these networks complement each other very well and a welldesigned cooperative strategy between both networks can bring significant benefits. Transmitting bits over short-range networks is much more energy efficient that doing it over cellular networks. In addition, short-range networks usually use spectrum-free bands (e.g., ISM bands).

WWRF has recognized the importance of short-range communications, creating a study group on this subject (WG5) back in 2004. Since then a number of highly relevant technologies have been actively explored jointly by academia and industry. The main focus of the short-range activities in WWRF is on air interface developments, and this is especially reflected in the contents of this book. Several white papers and briefings have been produced in recent years, dealing with the following subjects:

WWRF White Papers

- Multi-dimensional Radio Channel Measurements and Modelling for Future Mobile and Short-range Wireless Systems;
- UWB techniques and future perspectives;
- WBB over Optical Fiber;
- UWB Limits and Challenges;
- MIMO-OFDM for WLAN (TDD mode);
- Short-range Optical Wireless Communications;
- The Architecture of Mobile Internet;
- New Radio Interfaces for Short-range Communications;
- Gigabit LAN at 60 GHz;
- Cooperative Aspects of Short-range Systems.

WWRF Briefings

- Wireless Body Area Networks and Sensor Networks;
- High Throughput WLAN/WPAN;
- Gigabit WLAN Technologies;
- Visible Light Communications.

White papers and briefings on short-range communications at WG5 of WWRF

New research subjects are continuously identified, reflecting the interests of industry, academia and research institutes participating in WG5. The following subjects are currently being considered for further exploration in this group, leading to new briefing and white papers, thus becoming an integral part of the WWRF vision of future wireless communications.

New research subjects on short-range communications

- Car communications:
  - Car-to-Car,
  - Car-to-roadside,
  - Car-to-Infrastructure (jointly with WG4/cellular access group),
  - In-Car Communications.
- Ultra High Performance WLAN systems: Finding the limits of WLAN, targeting a bit rate of 100 GBps.
- Body Area Networks,
- Wireless Grids.

Identified new research items at WG5

The following chapters address aspects of the work on short-range communication of the last three years. They focus on several different aspects of UWB communications, ultra high speed communication at 60 GHz, visible light communication, UWB over fiber and also design rules for modern short-range communications systems. Our aim in publishing this book was to give a deeper insight in the important aspects and current research in short-range communication systems.

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