

## **CHAPTER 1**

### **INTRODUCTION**

**Anthony Ephremides**

#### **INTRODUCTION**

Rapid growth in wireless communications has recently stimulated numerous studies, workshops, reports, and other activities. All aim at fostering broad appreciation and understanding of the field as well as at formulating appropriate responses to trends in the development of related products and services. The WTEC study was sponsored by an impressive number of agencies of the U.S. government, led by the National Science Foundation. In fact, it was during a workshop sponsored by NSF in the summer of 1998 that a recommendation emerged to sponsor such a study. The objective was to assess long-term trends in research in the wireless communications area worldwide. A corollary objective was to use the findings to better formulate research funding priorities for the U.S. agencies that will help promote and maintain the competitiveness of the United States in this important technology area.

This introductory chapter describes the general parameters of the study and the approach that this panel took in addressing the sponsors' charge.

The first realization was that the field of wireless communications has multiple facets. To some people it conjures simply the image of cellular telephony and to others only propagation or fading phenomena. To the members of the WTEC panel, it represents the full gamut of applications that encompass cellular telephony, wireless LANs, Internet access, personal communications, telemedicine, other specialized applications, and, last but not least, military communications (which include diverse uses with corresponding unique requirements). It also encompasses, from the technology point of view, all the issues that traditionally correspond to the seven layers of the open systems interconnection (OSI) architecture that has governed the field of communications and networking in the last third of the 20th century.

This realization influenced the selection of the researchers and scientists who composed this panel, which contained truly distinguished experts and recognized authorities at all levels of the OSI model.

The second realization was that the task was enormous in light of the resources of the study. There has been such an intense and expansive growth in the field that almost every major company in the industrialized world, as well as literally hundreds, if not thousands, of mushrooming small players, have entered the technology and service arenas in this field. To fully assess the status of wireless communications in the world, the panel would have to engage in an impossible mission of visits and meetings, which, in addition to being prohibitively expensive, would require a length of time that would render the findings obsolete by the time the study concluded.

Thus, the panel decided to be selective. It concentrated on major companies and institutes and carefully selected a representative set in the United States, Europe, and Japan.

The third realization was that applications are often ahead of theory and have been leading the development of technology. As a result, the enormous financial stakes have created a very intense competitive environment among the world's major players. In turn, this has diminished the willingness to share not only current research and development plans but also longer-term plans.

Therefore, the panelists had to challenge their skills to infer the directions in which companies see the field evolving.

A related realization was that the rapidity with which the wireless technology is used in a variety of new applications has created an environment in which confusion (if not chaos) is common. Not only the general public but also the technology developers themselves lack a firm, commonly held vision as to what is important (both in terms of products as well as in terms of services).

Consequently, the panelists had to use their own expertise and understanding of the field to interpret and complement the inputs they received.

Finally, the panel members realized that the community is paying a great deal of attention to the physical, link, and media access control (MAC) layers in the field of wireless communications. This is the result of previously dominant needs in military communications (that have led and predated the development of commercial applications by many years) and in cellular communications.

Because of the emphasis on layering and because the panel members firmly believe (as do most of the representatives of the sites it visited) that in wireless communications, hardware and networking aspects will become increasingly important, if not dominant in the future, the panel decided to focus on all seven layers of the OSI architecture as well as on antennas and equipment.

## **APPROACH**

Based on the framework that emerged from these realizations during the early part of the study, the panel developed a plan that included a schedule with specific benchmarks as well as a strategy for approaching the subject. The goal was to maximize the efficiency of the data-gathering phase and to formulate a concept that would be true to the overall framework.

Thus, the schedule of activities was organized as follows. It commenced with a kick-off meeting of the panel (jointly with sponsors) in January 1999 in the Washington, DC area, during which the panel unfolded its strategy. A technical workshop followed in the Washington, DC area on March 15, 1999, in which most major U.S. companies active in the wireless communications area were invited to participate. The panel chose to canvas U.S. industry opinion in this manner (rather than through individual visits) purely for reasons of efficiency. Thirteen companies (listed elsewhere in the report) contributed inputs based on a questionnaire that the panel developed and forwarded to them ahead of time. The collection of viewgraphs from their presentations became (and still is) available from WTEC as a separate document.

Following that the panel took two weeklong trips to Europe and Japan, respectively, where it visited a total of 24 companies and institutes. These visits took place in April, May, and early June 1999. The intensity of the schedule necessitated splitting the group (consisting of panel members and of representatives of some of the panel's sponsors) into subgroups. Thus, no single individual in the group enjoyed first-hand contact with all of the visited sites. Shortly after the completion of these visits, a separate report for each site was generated, authored by a pre-designated member of the group but in wide consultation with and inputs from other panel members. These reports were sent to the visited sites for concurrence and, after revisions to

account for hosts' comments, became available on the WTEC Web site. They are now included, after final editing, as appendices C and D of this report.

At this point the panel needs to mention that representatives from some of the sponsoring agencies played a very active role in participating in the conduct of this study. Through their membership in the travel group, authorship of site-visit reports, and active deliberation with the panel, they provided valuable assistance in shaping the outcome of the study.

Exactly because the site visit reports were generated as separate documents, the panelists felt that the structure of the main analytical report should not follow the format of reporting findings from each site. Rather, it was decided to structure the report on the basis of technical areas.

Thus, the specific elements found at a particular site, as they pertained to one technical area, would be fused into the discussion of that area along with the appropriate elements found in other sites. In this way, the panel members believe they have produced a more informed and informative report that will be more useful to sponsors and to the community at large. In addition, under that structure, the findings would be consistent with the principles of the framework outlined in the introduction.

In deciding what technical areas to choose so as to form a spanning skeleton for the entire field, it was natural to follow the OSI layered architecture. Nevertheless, it is interesting to note that one of this panel's major findings is that the traditional separate consideration of networking layers is less useful in the wireless area. Indeed, the technical coupling among layers, always present even in nonwireless networks, is simply too strong in wireless systems to be ignored. The convenience that separation into layers provides is in large measure due to the fact that it ignores the interactions among layers. In wireless networks this convenience is countered by the neglect of crucial interactions (between multiple access and routing or between link control and compression, for example).

However, structuring the report along traditional layer lines does not contradict this finding. It simply permits a clean organization of the report. In fact, relationships among the layers are duly noted and reported as these arise. Thus, the chapters that follow in the main body of the report are centered, respectively, on the following topics:

- hardware (i.e., materials, devices, circuits, amplifiers, antennas, and system integration that optimize efficiency in wireless communication)
- antennas and signal processing (i.e., the "systems" aspects of antennas, including spatio-temporal processing to combat fading and interference and to shape adaptively the antenna patterns)
- channel modeling (i.e., statistical and empirical models that predict propagation patterns and signal attenuation)
- modulation/coding/access (i.e., link-layer issues that govern quality of point-to-point transmission)
- networking/switching (i.e., architecture and higher-layer issues that affect quality of service system-wide)
- integrated/holistic design (i.e., a novel viewpoint that starts from the realization of inter-layer coupling and exploits the possibilities of software-defined radios, energy efficiency, and other issues that cut across layers)

After a brief gestation period following the site visits and the composition of the site-visit reports, the panel held a final open workshop to disclose the preliminary findings of the study. This workshop was held in the Washington, DC area in September 1999 and was attended by a large audience. The collection of viewgraphs from the presentations by the panelists and the sponsors were posted on the WTEC Web site shortly after the workshop (now superseded there by this final report). The present report constitutes the final step in this study.

