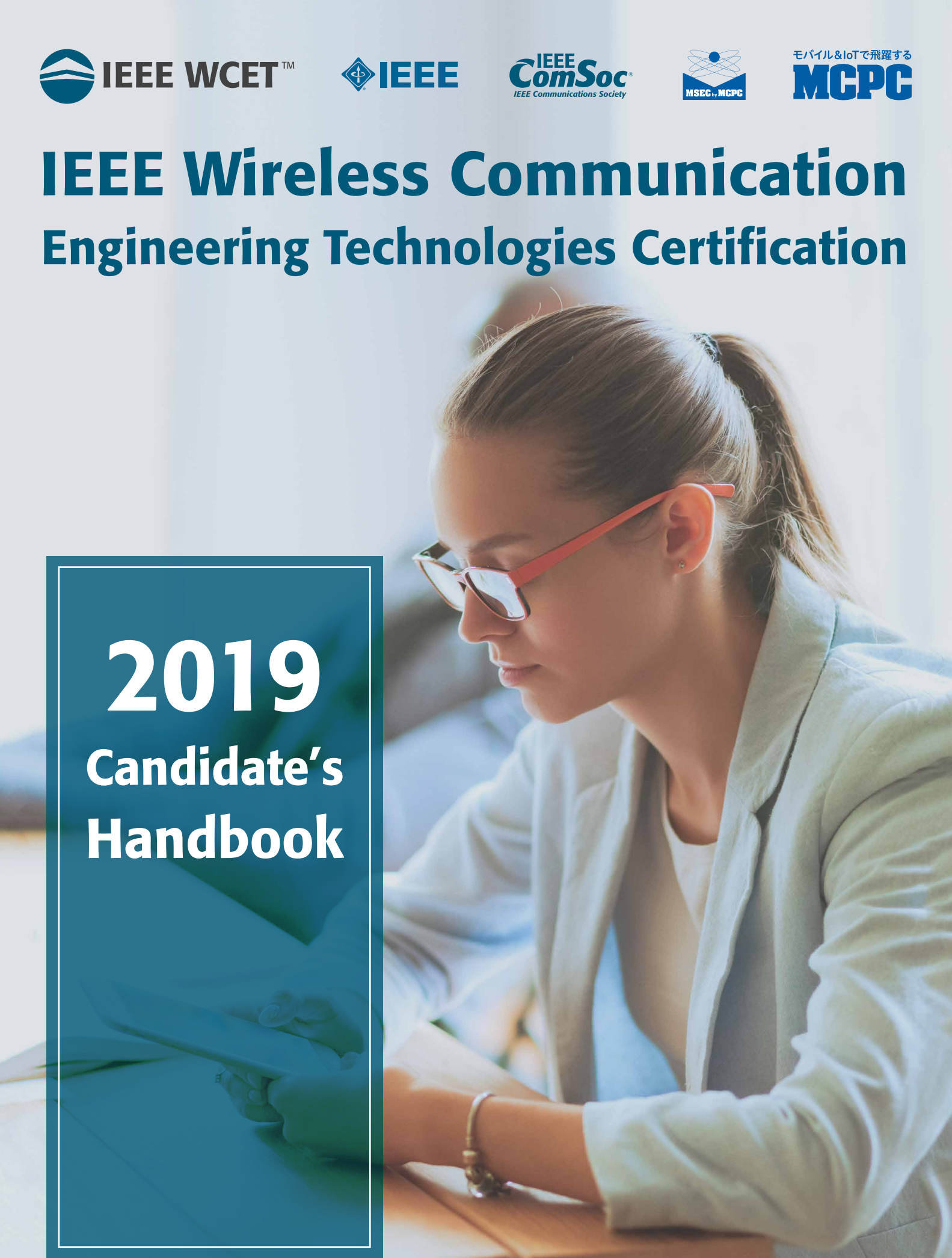


# IEEE Wireless Communication Engineering Technologies Certification



**2019**  
**Candidate's  
Handbook**

# QUICK REFERENCE GUIDE

## Contact Information

### IEEE WCET Certification Program

IEEE Communications Society (IEEE ComSoc)  
3 Park Avenue, 17th Floor  
New York, NY 10016 USA  
Tel: +1 212 705 8900  
Fax: +1 212 705 8999  
email: [cert@comsoc.org](mailto:cert@comsoc.org)  
website: [www.ieee-wcet.org](http://www.ieee-wcet.org)

### Pearson VUE

website: [www.pearsonvue.com/wcet](http://www.pearsonvue.com/wcet)  
Contact Pearson VUE to schedule your test  
after you receive your *Authorization to Schedule* email.

Important 2019 Dates	Testing Window	Application Period	Application Deadline
	22 April – 18 May 2019	2 January 2019 – 5 April 2019	5 April 2019 by 23:59 p.m. UTC
	23 September – 19 October 2019	22 April – 6 September 2019	6 September 2019 by 23:59 p.m. UTC

## Examination and Other Fees

IEEE WCET total examination fee for IEEE and IEEE ComSoc members

US\$450\*

IEEE WCET total examination fee for nonmembers

US\$550\*

Online practice examination

US\$50

*Starting in 2017, the recertification period is three years. See page 22 for information about recertifying depending on whether you currently hold a three-year or a five-year certification.*

Recertification fee for IEEE and IEEE ComSoc members

US\$180

Recertification fee for nonmembers

US\$210

**\*A nonrefundable US\$175 application fee is included in the total examination fee.**

## Application, Scheduling/Rescheduling, Withdrawal, Refund, and Other Information

### Apply for the IEEE WCET certification

Visit [www.ieee-wcet.org/apply](http://www.ieee-wcet.org/apply)

### Update your contact information

Email [cert@comsoc.org](mailto:cert@comsoc.org)

### Schedule an appointment

Visit [www.pearsonvue.com/wcet](http://www.pearsonvue.com/wcet) after receiving your Authorization to Schedule notice and continue online or by calling the appropriate office which can be found at [www.pearsonvue.com/pti/contact](http://www.pearsonvue.com/pti/contact)

### Cancel or reschedule an appointment

Visit [www.pearsonvue.com/wcet](http://www.pearsonvue.com/wcet) after receiving your Authorization to Schedule notice and continue online or by calling the appropriate office, which can be found at [www.pearsonvue.com/pti/contact](http://www.pearsonvue.com/pti/contact)

### Withdraw your IEEE WCET certification application (no appointment)

Send an email to [cert@comsoc.org](mailto:cert@comsoc.org) with "WITHDRAW WCET APPLICATION" in the Subject line

### Refund requests

Send an email to [cert@comsoc.org](mailto:cert@comsoc.org) with "WCET EXAM REFUND REQUEST" in the Subject line

### Special accommodation request

Send an email to [cert@comsoc.org](mailto:cert@comsoc.org) with "SPECIAL ACCOMMODATION REQUEST" in the Subject line

**For Questions, Concerns or Group Discounts Contact:** [cert@comsoc.org](mailto:cert@comsoc.org)

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## Introduction

### IEEE WCET Examination: Highlights

- Administered on computer at Pearson VUE Testing Centers worldwide.
- Consists of 150 scored questions plus 15 unscored randomly distributed pretest questions.
- Four hours are allotted to complete the examination.
- A scale score of 500 or higher, on a scale of 200 to 800, is required to pass.

### Certification Overview

#### What Is Certification?

Certification is a voluntary process by which individuals are assessed against predetermined standards for knowledge/skills/ competencies and granted a time-limited credential. Certified individuals are typically issued a certificate attesting that they have met the standards of the credentialing organization and are entitled to make the public aware of their credential.

Certification differs from an assessment-based certificate program in that successfully earning the IEEE Wireless Communication Engineering Technologies (IEEE WCET®) certification requires a broad educational and experience background. In contrast, an assessment-based certificate program is a relatively short non-degree granting program that provides instruction and training to aid individuals in acquiring specific knowledge/skills/competencies and designates that individuals have passed an end-of-program assessment derived from the learning/course objectives. Although assessment may be an integral part of a certificate program, the primary purpose of such a program is to provide instruction and training.

Certification sets those with the credential apart from those without it. Advantages of obtaining certification include public recognition of professional achievement, within and outside the profession, achieving a personal professional goal, testing one's knowledge and measuring it against peers, and aiding in career advancement.

#### The IEEE WCET Certification Program

The IEEE Communications Society (IEEE ComSoc) has designed the IEEE WCET® certification program to address the worldwide wireless industry's growing and evolving need for qualified communication professionals who can demonstrate practical problem-solving skills in real-world situations. Individuals who achieve this certification will be recognized as having the required knowledge, skill, and ability to meet challenges in various wireless industry, business, corporate, and organizational settings.

#### Purpose and Use of Certification

The IEEE WCET® certification shows that an individual has demonstrated mastery of the internationally recognized body of wireless communication knowledge and has accepted the challenge to stay informed of new developments in the wireless field. The IEEE Wireless Communications Professional® (IEEE WCP) credential is a visible reminder to peers and co-workers of an individual's significant professional achievement.

The WCET certification is completely voluntary. Organizations or individuals incorporating WCET certification as a condition of employment or advancement do so of their own volition. Individuals should determine for themselves whether certification, including recommended education or experience and recertification requirements, when coupled with any other requirements imposed by individuals or organizations, meets their needs and complies with applicable laws.

## IEEE WCET Examination Overview

### IEEE WCET Examination

The IEEE WCET examination is administered on computer and consists of 150 scored multiple-choice questions plus 15 unscored pretest questions randomly distributed throughout the examination. Questions on the examination are in English and are based on the most recently published test specifications (see Appendix A). Each question lists four possible answers, only one of which is the correct or “best possible” answer. The answer to each question can be derived independently of the answer to any other question. Four (4) hours are allotted to complete the examination. **A basic four-function, non-scientific calculator will be available online for use during the examination.** Before the exam date, candidates should visit the Pearson VUE Testing Tutorial at [www.pearsonvue.com/athena](http://www.pearsonvue.com/athena) to become familiar with the computer-based testing system. Applicants should be familiar with the use of a computer mouse and a windows-based GUI interface. A glossary of commonly used wireless communication terms, in addition to a list of constants, conversions and equations will be available via a link during the examination process. The glossary and constants, conversions and equations are presented in Appendices D and E in this Handbook and are also available at [www.ieee-wcet.org/glossary.html](http://www.ieee-wcet.org/glossary.html). A candidate must obtain a scale score of 500 or higher, on a scale of 200 to 800, in order to pass the examination and receive his or her certification.

### Use Of A Calculator During The IEEE WCET Certification Exam

Please note that the calculator provided during the exam is not a scientific calculator. The decision to not provide a scientific calculator was made after careful consideration of the level of difficulty of the exam questions. While a scientific calculator is helpful in some practical situations, all of the exam questions can be answered without using one, and most questions can be answered without using a calculator at all.

### IEEE WCET Examination Areas of Expertise

The IEEE WCET examination consists of questions in several different areas of expertise. The test specifications describing each of these areas, the examination weightings (the percentage of questions allocated to each area of expertise), and the detailed skills and knowledge covered in each area are contained in Appendix A. The examination is regularly reviewed and updated by a panel of IEEE WCET subject matter experts to ensure that the questions are current and reflect the current published test specifications.

## IEEE WCET® Certification Denial and Revocation Appeals

### Denial or Revocation of WCET Certification

Applications may be denied or certifications revoked for any of the following reasons:

- Falsification or misrepresentation of information on the examination application;
- Violation of testing procedures;
- Failure to pass the certification examination; or
- Failure to meet recertification requirements.

Candidates whose applications are denied or certifications revoked for any of the above reasons will be notified in writing. Candidates may appeal the decision to the WCET Appeals Board by submitting an appeal in writing. Appeals must:

- Be in writing, signed by the candidate;
- Be sent to IEEE Communications Society - WCET by certified mail;
- Explain the specific reason(s) for appeal;
- Be accompanied by evidence or other pertinent information refuting the original decision; and
- Be postmarked no later than ten (10) business days after the notification date on the letter denying or revoking certification.

Appeals should be addressed to:

IEEE WCET Appeals Board  
IEEE Communications Society  
3 Park Avenue, 17th Floor  
New York, NY 10016 USA

### Appeals for WCET Certification Denial and Revocation

Appeal requests will be reviewed by the WCET Appeals Board composed of two WCET Steering Committee members or their designees, one WCET professional, one WCET staff member, and an attorney if deemed appropriate. The Appeals Board will review the request within 15 business days of receipt, during which the Board may request additional documentation. All information received will be considered strictly confidential and will be used only to review the appeal.

Candidates submitting an appeal will receive written notification of the decision within 30 days of receipt of the request. This notification will also be provided to the WCET Steering Committee. The WCET Appeal Board's decision is final.

## Applying for the Exam: Checklist

- Check your education and experience against WCET recommendations.
- Complete an application at [www.ieee-wcet.org/apply](http://www.ieee-wcet.org/apply).
- Applications are due 5 April 2019 for testing during the Spring window and 6 September 2019 for the Fall window.
- Your name and address submitted on your application must match the two forms of ID you will use as proof of identity at the testing center. Please see page 16 for acceptable forms of ID.

## Recommended Education and Experience

The WCET examination is a broad-based test that assesses knowledge of the entire wireless communication engineering field. ***If you have never been a wireless communication engineering practitioner, or do not plan to become one, you will need to evaluate whether it is appropriate for you to take this examination.*** The WCET examination is intended for professionals who develop and implement all types of wireless communication in countries around the world.

The WCET exam has been constructed by subject matter experts to assess the skills and knowledge of practicing wireless communications professionals with the equivalent of a college or university degree and three or more years of professional experience. The decision as to whether an individual is prepared to take the exam is an assessment that should be made by the applicant with this understanding. In making the decision, an applicant should consider the following factors:

- The college or university should be accredited in the country in which it is located.
- Graduate-level educational experience may be comparable to an equivalent period of professional work experience.
- “Professional wireless experience” means that at least 51% of the candidate’s activities are in the field of wireless communication engineering and are at the professional level.
- A thorough familiarity with the topics covered by the exam, as described in Appendix A of this Handbook, is necessary to achieve success on the examination.
- Success on the WCET practice exam, available online, has been shown to be an indicator that a candidate is probably prepared to take the certification examination.
- Applicants with a combination of a bachelor’s degree or comparable education plus three or more years of professional experience – or other similar level of preparation – have been more successful on the examination than those with less preparation.

The examination reflects current wireless communication engineering practices. Although the three years of professional wireless communication engineering experience need not be current or sequential, recent experience is more likely to coincide with the content of the examination.

Candidates with questions about the recommended education or experience can send an email to [cert@comsoc.org](mailto:cert@comsoc.org). Ultimately, however, it is up to each candidate to decide if his or her level of education and experience is sufficient to apply for the examination.

The WCET certification program does not discriminate on the basis of race, religion, national origin, gender, sexual orientation, or disability. IEEE Membership is not a requirement to take the exam and nothing in the preceding statements should be so interpreted.

## Application and Examination Fees

The examination fee is US\$450 for IEEE or IEEE ComSoc members and US\$550 for nonmembers. This includes a US\$175 nonrefundable application fee. If you would like to learn more about membership in IEEE, visit [www.ieee.org](http://www.ieee.org) for more information. Candidates must be full members of IEEE at the time of application in order to receive the discount and must include their IEEE membership number in the relevant area on the application. If your membership number is valid, you will be able to complete the application and pay the US\$450 fee. If not, you will need to pay the US\$550 fee.

***Organizations or employers may sponsor candidates for the examination. Candidates who are being sponsored by an employer will receive special instructions via email on how to submit their application.***

Examination fees are due at the time of application submission. Applicants may pay by VISA, MasterCard, or American Express.

## Testing Windows and Application Deadlines

The “testing window” is the time period during which the WCET examination is offered. In 2019 and future years, it is anticipated that there will be two testing windows annually. The 2019 testing windows run from 22 April – 18 May 2019 and from 23 September – 19 October 2019. Candidates may test on any date during the testing window, depending on the availability of appointments at Pearson VUE testing centers.

Each testing window has a specific application deadline. Applications for the Spring 2019 testing window will be accepted 2 January 2019 through 5 April 2019. Applications for the Fall 2019 testing window will be accepted from 22 April through 6 September 2019. Application and testing dates for 2020 will be finalized by October 2019.

## Special Accommodation Requests

IEEE ComSoc will, to the best of its ability, accommodate candidates with disabilities who need special arrangements to take the examination. Auxiliary aids and services will be provided except where these may fundamentally alter the examination or result in an undue burden. Pearson VUE may be unable to comply with special accommodation requests made by candidates taking the examination where local operating conditions or local laws and customs render such requests unlawful, impossible, or economically unfeasible to perform.

A special accommodation request must be made by the candidate at the time of application by sending an email to [cert@comsoc.org](mailto:cert@comsoc.org) with “SPECIAL ACCOMMODATION REQUEST” in the Subject line. The nature of the disability, identification of the test(s) and protocols used to confirm the diagnosis, a description of past accommodations made for the disability, and the specific testing accommodations requested must be detailed in the email request. All information submitted will be kept confidential.

## Completing and Submitting the Application

*Please read this Handbook carefully before applying to take the examination.*

Submission of an application attests that you have read this Handbook and agree to be bound by all policies and procedures set forth herein. It also attests that all information presented in the application is correct and that you will abide by IEEE ComSoc's decision should any information be judged to be misrepresented or fraudulent. Further, you are granting permission to IEEE ComSoc to make any inquiries that may be necessary to verify your submission information. Finally, you are agreeing to abide by the rules and decision of IEEE ComSoc and understand that falsification of information on your application is grounds for refusing or revoking certification.

To apply for the WCET examination, go to [www.ieee-wcet.org/apply](http://www.ieee-wcet.org/apply). When completing the application, you will be asked to provide contact information and payment information. You will be asked to upload a copy of your government issued ID and to answer some demographic questions. Please verify that the information you have entered online is correct before you submit the application.

All candidates who submit an application will receive a confirmation email within 24 hours indicating that their application and exam fee was successfully transmitted. Candidates will subsequently receive via email an Authorization to Schedule notice providing information on how to schedule the examination. Authorization to Schedule notices will be emailed to all candidates within seven (7) business days of receipt of a completed application. This notice will provide candidates with the information needed to schedule an examination.

Applicants are strongly advised to apply online well in advance of the deadlines, since the volume of applications on the last day of the application period can be heavy. IEEE ComSoc and Professional Testing are not responsible for system problems (e.g., website down or slow, etc.).

## Updating Contact Information

### Address Changes

If your address changes at any time during the application period or testing window, then you must send an email to [cert@comsoc.org](mailto:cert@comsoc.org) with "WCET ADDRESS CHANGE" noted in the Subject line.

### Name Changes

It is important to notify IEEE ComSoc promptly of any name changes for two reasons: (1) if the name on your unexpired government-issued ID does not match the name on your Authorization to Schedule notice, you may be denied admission into the testing center, and (2) the score report and certificate will not display your name correctly.

Testing Center staff will require two forms of ID. If the name on your record does not match the name on your ID, you may be denied admission, in which case you will forfeit the testing fee.

If you find that there is a discrepancy between the name on your record and the name on your official ID, send an email to [cert@comsoc.org](mailto:cert@comsoc.org) with “WCET NAME CHANGE” noted in the Subject line.

To change your name because of a legal name change (e.g., marriage, divorce), you must submit notarized documentation to IEEE ComSoc by mail, email, or fax at least ten (10) business days before your scheduled examination appointment. It is strongly recommended that candidates use a traceable mailing method (e.g., certified or registered mail or expedited mail service that requires a signature) and/or keep a copy of the fax confirmation page to verify delivery. Do not send originals because these documents cannot be returned. When submitting a name change, make sure that you have an unexpired government-issued ID that matches the requested name.

## **Application Audits**

Submission of an application indicates your agreement to comply with the terms of the audit process. Applications are selected at random for audits in keeping with the IEEE Code of Ethics primarily to ensure that a candidate has not provided false or misleading information in the application. You may be asked to provide evidence to support the information you provided on your application. If you successfully complete the audit, you will be eligible to sit for the examination. If you fail to meet the audit requirements, you will forfeit both the application and the examination fees.

## After Applying for the Examination: Reminders

- After applying and paying the fee, you will receive an Authorization to Schedule notification email.
- Locate a testing center closest to you at [www.pearsonvue.com/wcet](http://www.pearsonvue.com/wcet).
- Schedule your appointment online or by phone as far in advance as possible to secure your desired test date.
- Cancel or reschedule at least 24 hours prior to your scheduled date.
- Read the policies on Appointment Changes, Withdrawals, and Refunds carefully.

## Schedule an Appointment

Once you have submitted your application and paid the exam fee, you will receive an Authorization to Schedule email. This email includes a unique ID number, which is needed to schedule the exam.

You may schedule your exam online or by phone. When scheduling an appointment, the following information will be required:

- Your name exactly as it is printed on the Authorization to Schedule notice and the unexpired government-issued ID you will use to confirm your identity at the testing center;
- Your ID number as it is listed at the top of the Authorization to Schedule notice;
- Your daytime telephone number; and
- The name of the examination sponsor (IEEE Communications Society).

To schedule online, go to the IEEE ComSoc examination section of the Pearson VUE website, [www.pearsonvue.com/wcet](http://www.pearsonvue.com/wcet), and click on “Schedule Online.” You will be prompted to create a login and password and then schedule the exam. To schedule by phone, go to the IEEE ComSoc examination section of the Pearson VUE website, [www.pearsonvue.com/wcet](http://www.pearsonvue.com/wcet), and click on “Schedule by Phone” to find the phone number and hours of operation for the call center for the appropriate country. A customer-service agent will work with you to find the most convenient testing center and time. Candidates scheduling by phone will not receive written confirmation of their appointment unless they have provided an email address, so it is imperative to note the appointment details and appointment confirmation number.

Upon scheduling, you will receive a confirmation email from Pearson VUE. If you do not receive the email, you may not have completed the scheduling process. After checking your spam folder, you should call Pearson VUE to ask for the confirmation email.

IEEE ComSoc urges candidates to schedule exams as soon as convenient after application approval. The earlier you schedule, the more likely that a preferred time and place will be available. The exam authorization is valid for the current exam testing window only. If you wish to move to another testing window you forfeit the \$175.00 application processing fee.

Your appointment confirmation number is different from your ID number. Make sure you retain your appointment confirmation number since it is required to confirm, reschedule, or cancel an appointment.

Those scheduling an appointment within 48 hours of the end of the application window must do so by phone only. To schedule by phone, call Pearson VUE at the number listed on your Authorization to

Schedule notice or contact the appropriate Regional Office which can be found at [pearsonvue.com/pti/contact](http://pearsonvue.com/pti/contact).

Candidates who cancel their examination appointments but do not request a refund will forfeit all fees. Candidates who do not schedule an appointment and do not request a refund are considered no-show candidates and forfeit all fees. For more information, see the “Refunds” section of this Handbook.

***Candidates should verify their appointments as soon as possible, but no later than three business days before the scheduled exam.***

## **Schedule an Appointment Early**

Candidates should schedule their examination appointment as soon as possible after receiving their Authorization to Schedule notice. Candidates who delay scheduling their examination until the testing window has opened run a significant risk of not being able to schedule their test at a time and location of their choice. In rare instances, candidates who attempt to schedule/reschedule their appointment or change their testing center location late in the testing window may find that they are unable to schedule an examination date and location. If this occurs, candidates may withdraw from the examination and apply for a 50% refund (US\$137.50 for IEEE and IEEE ComSoc members and US\$187.50 for nonmembers) of their examination fee (see the “Withdrawals” and “Refunds” sections in this Handbook). The US\$175 application fee is nonrefundable.

## **Testing Center Locations**

Pearson VUE maintains over 200 Pearson Professional Centers throughout the United States, US territories and Canada as well as approximately 5,000 test centers in 180 countries worldwide. For a full list of centers or to locate the center closest to you visit <http://www.pearsonvue.com/wcet/> or call the Regional Headquarters below serving your region. ***It is advisable to physically locate or, if possible, visit the test location before examination day to make sure you can find the testing center and that you are aware of transportation and parking requirements.*** Pearson VUE maintains three regional headquarters, as follows:

### **The Americas**

Bloomington, MN USA – Corporate Headquarters  
+1-952-681-3000

### **Asia-Pacific Region**

Uttar Pradesh, India – Regional Headquarters  
+91-120-4001600

### **Europe, Middle East, Africa Region**

Manchester, United Kingdom – Regional Headquarters  
+44 (0) 161 855 7000

## Appointment Changes, Withdrawals, and Refunds

### Appointment Rescheduling and Testing Center Changes

Candidates can reschedule examination appointments within their testing window. However, testing windows cannot be changed. If necessary, candidates can change their testing center location. **IEEE ComSoc shares the Pearson VUE testing centers with many other organizations, so testing center seats fill up quickly. Candidates are advised to reschedule as early as possible.**

Candidates may cancel an exam (by phone or online) without penalty up to 24 hours before their appointment. Candidates may make a new appointment – without incurring a fee – then or at another time. ***If a candidate fails to keep an appointment without canceling on time, he or she will be considered a no-show and will forfeit the exam fee.***

Candidates who attempt to reschedule their appointment and/or testing center location late in the testing window cannot be guaranteed that a seat will be available and risk forfeiting the examination fee. If this occurs, candidates should withdraw and apply for a 50% refund (US\$137.50 for IEEE and IEEE ComSoc members and US\$187.50 for nonmembers) of their examination fee (see the “Withdrawals” and “Refunds” sections in this Handbook) in order to not be considered no-show candidates. The US\$175 application fee is nonrefundable.

***To reschedule an appointment and/or testing center location, contact Pearson VUE at [www.pearsonvue.com/wcet](http://www.pearsonvue.com/wcet), call the number shown in your Authorization to Schedule notice, or contact your Pearson VUE Regional Office.***

### Withdrawals

Candidates who have a scheduled appointment, as well as candidates who have not scheduled an appointment with Pearson VUE, may withdraw from the WCET examination. To withdraw from the examination, candidates must do the following:

#### Candidates Who Have a Scheduled Examination Appointment

Candidates who have a scheduled appointment may withdraw from the examination by cancelling their appointment with Pearson VUE. To cancel an appointment, contact Pearson VUE at [www.pearsonvue.com/wcet](http://www.pearsonvue.com/wcet), call the number shown in your Authorization to Schedule notice, or contact your Pearson VUE Regional Office which can be found at [www.pearsonvue.com/wcet](http://www.pearsonvue.com/wcet).

Once you have cancelled with Pearson VUE, you must submit your notification of withdrawal via email to [cert@comsoc.org](mailto:cert@comsoc.org) with “WCET EXAM WITHDRAWAL” noted in the Subject Line. The withdrawal information must be submitted on or before the last day of the testing window in order to receive a refund. See the following section on Refunds for more information.

#### Candidates Who Have Not Scheduled an Examination Appointment

Candidates who have not scheduled an appointment and who wish to withdraw from the examination must submit their notification of withdrawal via email to [cert@comsoc.org](mailto:cert@comsoc.org) with “WCET EXAM WITHDRAWAL” noted in the Subject Line. The withdrawal information must be submitted on or before the last day of the testing window in order to receive a refund.

## Refunds

Candidates who withdraw from the examination on or before the last day of the application period will receive a refund of their examination fee. If they have scheduled an examination appointment, they must notify Pearson VUE of their withdrawal. The US\$175 application fee is non-refundable. To initiate the refund, candidates must submit their Examination Withdrawal request via email to [cert@comsoc.org](mailto:cert@comsoc.org) with “WCET EXAM WITHDRAWAL” noted in the Subject line before the last day of the testing window.

Candidates who withdraw from the examination after the last day of the application period, but no later than 12:00 noon (Regional Office time) five (5) days before their examination appointment will receive a 50% refund of their examination fee (US\$137.50 for IEEE and IEEE ComSoc members and US\$187.50 for nonmembers). The US\$175 application fee is nonrefundable. They must first notify Pearson VUE that they are cancelling the appointment.

Candidates who do not cancel their examination appointment within the specified time frame and/or do not appear for an examination appointment are considered no-show candidates and forfeit all fees.

Candidates who cannot take the examination due to a medical or personal emergency should refer to “Refunds for Medical or Personal Emergencies” below.

Candidates who do not schedule an examination appointment with Pearson VUE or who do not submit their Examination Withdrawal request via email to [cert@comsoc.org](mailto:cert@comsoc.org) on or before the last day of the testing window are considered no-show candidates and forfeit all fees.

All candidates will need to provide the following Examination Withdrawal information in order to obtain a refund:

- Candidate’s full name as it appears on the application;
- Candidate’s postal and email addresses;
- ID number (found in the Authorization to Schedule notice);
- Testing center location (if applicable);
- Examination appointment date and time (if applicable); and
- Date and time the appointment was canceled (if applicable).

No refunds will be issued unless candidates submit their Examination Withdrawal information within the specified timeframe. Refunds are issued no later than four (4) weeks after the close of the testing window.

### Refunds for Medical or Personal Emergencies

IEEE ComSoc recognizes that medical or personal emergencies may arise that prevent candidates from rescheduling or withdrawing from an examination appointment. In such cases, candidates may request a partial refund of their examination fee by submitting a written request to [cert@comsoc.org](mailto:cert@comsoc.org) and including supporting documentation as to the nature of the medical or personal emergency (e.g., accident report, medical documentation, death certificate). Refund requests resulting from medical or personal emergencies will be reviewed on a case-by-case basis and candidates will be notified by email of the outcome of the request. If approved, candidates will receive a refund of their examination fee minus the nonrefundable US\$175 application fee. Examinations cannot be rescheduled to a future testing window.

Candidates should also cancel their appointment by contacting Pearson VUE at [www.pearsonvue.com/wcet](http://www.pearsonvue.com/wcet), calling the number shown in their Authorization to Schedule notice, or contacting their Pearson VUE Regional Office. They will be requested to submit copies of the supporting documentation in order to avoid incurring a cancellation fee.

Medical or personal emergency refund requests must be made in writing to IEEE ComSoc on or before the last day of the testing window and must include a description of the situation and documentation of the emergency or extenuating circumstance. Candidates whose examination appointments were scheduled for the last two (2) days of the testing window may submit the refund request no later than five (5) business days from the last day of the testing window. Requests received after that time and/or without documentation will not be reviewed.

### **What Is a Medical or Personal Emergency?**

IEEE ComSoc considers a medical emergency to be an unplanned medical event that arises within 48 hours of the scheduled examination and prevents candidates from taking the examination. The medical emergency may apply to candidates themselves or to one of the candidate's immediate family members (spouse, child, or parent). Medical events that can be anticipated as occurring on or near the examination date or any of the dates on which candidates can schedule, reschedule, or withdraw from the examination are not considered medical emergencies.

Inability to take the examination due to workload or work conflicts or to an inability to properly prepare for the examination is not considered a personal emergency.

### **No-Show Candidates**

A candidate who does not show up for an examination appointment without at least 24 hours notice will be considered a no-show. Likewise, a candidate who arrives late and is not admitted, fails to present adequate identification, or refuses the Nondisclosure Agreement, will not be allowed to take the exam and will be considered a no-show. A no-show is treated like a failed exam. No-shows will only be allowed to schedule a new exam appointment upon payment of the retest fee.

## Studying for the Examination: Helpful Hints

- The Appendices in this Handbook provide information that may be helpful in preparing for the exam.
- ComSoc offers books, courses, and tutorials that may also be helpful, although they are not designed to “teach the exam.”
- An online practice exam can be purchased as an additional means of preparing.

Candidates should prepare thoroughly for the examination. The following are some of the available resources to assist in this preparation.

**Appendix B** in this Handbook contains a short list of relevant references. This list is provided solely as an example and these references should not be considered the only possible study options.

**Appendix C** in this Handbook contains a few sample questions that are similar in form and content to those that appear on the certification examination.

**Appendix D** in this Handbook contains a glossary of acronyms and Appendix E lists constants, conversions, and equations that candidates should be familiar with before taking the examination. This glossary and the equations will also be available for online reference during the examination.

**The Wireless Engineering Body of Knowledge (WEBOK) 2<sup>nd</sup> edition**, published by IEEE ComSoc, is a review text that outlines the topics that may be covered on the examination. It includes numerous references in which detailed wireless communications knowledge can be found.

The WEBOK can be ordered from John Wiley Publishers.

[www.wiley.com](http://www.wiley.com)

Call +1 877 762 2974 (US)

+1 800 567 4797 (Canada)

+1 44 1243 843294 (world)

ISBN: 978-1-118-34357-9 Paper, 316 pp, 2015

Price: US\$80.95 (save 15% using Promo Code: 18493)

**Practice Exam.** Before applying for the examination, candidates should consider taking an **online practice exam** consisting of 75 questions similar to those on the actual examination. The fee for the practice exam is US\$50. For more information visit [www.ieee-wcet.org/practice.html](http://www.ieee-wcet.org/practice.html).

**IEEE ComSoc Training.** Online courses addressing some of the topical areas covered by the exam can be purchased from IEEE ComSoc Training. Visit [www.comsoc.org/training](http://www.comsoc.org/training) for more information.\*

**IEEE ComSoc’s Free Tutorials Now.** Free tutorials that may be of interest or helpful to you are available through IEEE ComSoc’s Free Tutorials Now program. Visit [www.comsoc.org/free-tutorials](http://www.comsoc.org/free-tutorials) for more information.\*

*\*None of the training or tutorials offered by IEEE ComSoc is geared to teach an individual how to pass the WCET Certification exam. These resources can help in exam preparation but completing a course or tutorial will not guarantee your ability to pass the exam.*

## On Examination Day: Reminders

- Admittance to the testing center is by appointment only.
- Arrive 15 minutes before your appointment; late arrivals may not be accommodated and may be considered a no-show resulting in a retesting fee to reschedule the exam.
- Review the list of acceptable IDs and bring two unexpired forms to the testing center. Make sure your name on the IDs matches the name on your application.
- Review the testing center rules on food, drinks, personal items, and breaks.
- An electronic signature and digital photo are required; a palm-vein scan may be required at some centers.
- All examinations are monitored and may be recorded in audio and video.
- To take the exam, candidates must acknowledge that they have read, understand, and accept the Security Acknowledgement and Agreement.
- Candidates may not leave the site while taking the exam.

## Admission to the Testing Center

Once a candidate makes an examination appointment, he or she will receive a confirmation email from Pearson VUE. The email confirms the address of the testing center. Candidates should arrive 15 minutes before the scheduled appointment. Late arrivals may not be accommodated; in that case, a candidate is considered a no-show and has to pay the retesting fee to reschedule the exam.

Candidates need two forms of identification for admission: a primary ID and a secondary ID. The name that appears on the two forms of identification must match the name under which the candidate is registered to take the exam. ***Do not register under a nickname!*** If a name change is needed, candidates must contact IEEE ComSoc at least 10 days before the testing appointment to change the name on the record.

The following forms of ID are accepted as primary ID:

- Government-issued driver's license
- State/national identification card
- Passport†
- Military ID†
- Alien registration card (green card, permanent resident visa)
- U.S. Passport card or equivalent document issued by another country
- U.S. Dept. of State Driver's License or equivalent issued by another country

† The primary ID must contain a photo and signature unless the signature is embedded in the identification. When this occurs, the candidate must present another form of signature identification from the primary or secondary list.

The following forms of ID are accepted as secondary ID:

- Any ID on the primary list
- U.S. Social Security card or similar document issued by another country
- Credit/bank ATM card (signature required)

## Testing Center Rules

- Arrive at the testing center at least 15 minutes before your scheduled reporting time.
- The exam administrator at the testing center will not allow test takers to take personal items – including reference materials and electronics – with them into the exam area. Although locker storage is normally offered, it is best not to bring large bags, jewelry, electronics, and the like to the testing center. Consideration will be made for comfort items such as pillows and tissues or medical necessities such as crutches; the exam administrator is required to inspect such items.
- All candidates must present an unexpired government-issued ID bearing their photo and signature to be admitted to the testing center (see the section above “Admission to the Testing Center”). Your ID must match the name you provided on your application and the name that appears on your Authorization to Schedule notice, and the photo must validate your identity.
- As part of Pearson VUE’s test-security program, a palm-vein scan is required at some testing centers. An electronic signature and digital photo are required at all centers.
- Admittance to the testing center is by appointment only. Candidates must be present at the time and location of their appointment to be admitted.
- No test materials, documents, or memoranda of any sort may be taken into or from the test room.
- Candidates will receive an erasable note board or a small notebook consisting of erasable and reusable pages for use during the exam. They are to be returned to the exam administrator at the completion of the exam.
- Candidates will have the opportunity after the examination to submit general comments or comments about specific examination questions by following the applicable onscreen instructions. The IEEE ComSoc Examination Committee will review all comments but will not provide written responses to comments.
- Smoking is prohibited.
- Candidates may not ask questions about examination content.
- All examinations are monitored and may be recorded in both audio and video format.
- No breaks are scheduled during the examination. Candidates who have to leave the testing room to take a break will not be given extra time on the examination. To re-enter the testing room, candidates must have their palm rescanned (if required) and must sign in and present their identification documents.
- Candidates may not leave the testing site facility while the examination is in progress.
- IEEE ComSoc and Professional Testing reserve the right to cancel any test score believed to be obtained in a questionable manner.
- Food, drinks, purses, briefcases, notebooks, calculators, pagers, cellular telephones, recording devices, and photography equipment are not allowed into the testing room.
- It is expressly prohibited to disclose, publish, reproduce, or transmit any part of the examination, in any form, by any means, verbal or written, for any purpose, without the express written permission of IEEE ComSoc. Violation may result in civil or criminal prosecution.
- Medications that may need to be accessed during the test can be stored in lockers outside the testing room. Candidates who will need to use crutches or other medical equipment should complete a special accommodation request form as described in the “Special Accommodation Requests” section of this Handbook so that the testing center can be informed in advance.

- Religious headwear may be worn into the testing room; however, it may be subject to inspection by a testing center administrator before entry into the testing room is permitted.
- Candidates are expected to behave in a civil manner when on the premises of the testing center. Exhibiting abusive behavior toward the testing center staff or other testing candidates may result in forfeiture of your examination and/or criminal prosecution.
- Visit Pearson VUE's website to view the complete Rules Agreement.

Please remember that other examinations are being administered at the same time that you are taking the IEEE WCET examination so you may hear typing on keyboards for an essay examination, coughing, and/or people entering and leaving the testing room. It is impossible to provide a completely noise-free testing environment. The testing center administrator may provide candidates with small earplugs that can be inserted inside the ear if requested. Candidates are not allowed to bring in headsets or headphones.

### **Biometrics**

As part of Pearson VUE's test-security program, a palm-vein scan is required at some testing centers. An electronic signature and digital photo are required at all centers.

### **Inclement Weather**

Pearson VUE policy is to remain open whenever possible. However, when it is impractical to remain open, Pearson VUE will give candidates as much notice as possible. In such cases, candidates can reschedule without penalty.

### **Name Discrepancies**

Candidates with minor name discrepancies may be admitted at the administrator's discretion if all available IDs have been checked and it is believed the candidate is the same person shown on the IDs. Acceptable discrepancies include:

- discrepancies due to technical limitations (e.g., name shortened);
- typographical errors (e.g., minor misspellings); or
- Traditional/ cultural variations (e.g., abbreviated or shortened names, initials, missing middle names).

Candidates with hyphenated last names whose photo IDs show only one of the last names may be admitted if the single name matches part of the hyphenated name and the signature and photograph clearly match.

Candidates whose middle names are spelled out on their ID but are listed with an initial on the application may be admitted as long as the initial matches the first letter of the middle name and the signature and photograph match. This also applies to candidates who use their middle name instead of their first name on their application but their ID displays their first, middle, and last names.

## Security Acknowledgement and Agreement

Prior to taking the examination, candidates will be presented with a security acknowledgement screen. Candidates must acknowledge that they have read, understand, and accept the conditions listed below.

1. I have an ethical duty to protect the security of the IEEE WCET® Certification Examination.
2. The examination and questions contained therein are the exclusive property of the IEEE Communications Society – WCET Certification Examination Program.
3. This examination and the questions contained therein are protected by copyright law and constitute valuable trade secret information, the disclosure of which will cause injury to the IEEE Communications Society – WCET Certification Examination Program. No part of this examination may be copied or reproduced in part or whole by any means whatsoever, including memorizing and/or reporting question or examination content.
4. The dissemination of question or examination content to any person, organization, company, or other entity in any manner shall constitute a breach of professional ethics and theft of the exam. Any person found guilty of such violation may have his/her score voided. The IEEE Communications Society may prohibit the candidate from future access to the WCET Certification Examination.
5. The theft or attempted theft of an examination or examination items is punishable as a felony and may result in civil penalties and/or professional sanction. I recognize that the breach of my obligations under this candidate acknowledgment may expose me to liability for damages caused to the IEEE Communications Society and to legal fees incurred by the IEEE Communications Society in preserving its rights.
6. I understand that during the examination, I may not communicate with other candidates, refer to any materials other than those provided to me, or assist or obtain assistance from any person. Failure to comply with these requirements may result in the invalidation of my examination results as well as other appropriate action.
7. My participation in any irregularity occurring prior to, during, or subsequent to this examination, such as giving or obtaining unauthorized information or aid, as evidenced by observation or subsequent statistical analysis, may result in termination of my participation, invalidation of my examination results, or other appropriate action.

Candidates who do not agree to the conditions listed above will not be allowed to proceed and take the examination, and will forfeit both the application and examination fee.

### Taking the Test

Candidates should answer easy questions first and mark the more difficult ones to return to later. There is no penalty for guessing, so candidates should answer all the questions, if possible. There are optional survey questions at the end of the examination that candidates are encouraged to answer. Responses are confidential. The information collected is used for statistical purposes only.

## After the Examination: What's Next

- A score report will be available three to four weeks after the testing window.
- You will be notified by email with your official score report.
- If you pass, your certificate will be mailed to the address provided in the application.
- If your address changes, email [wcetcertificates@comsoc.org](mailto:wcetcertificates@comsoc.org).
- Candidates who fail may re-apply to test at a reduced fee.

## Receiving Examination Results

An official score report will be available approximately three to four weeks after the close of the testing window. You will be notified by email with your official score report. If you have passed, your certificate will be mailed to the postal address provided in the application, so make sure that you update your address if it has changed. Email [cert@comsoc.org](mailto:cert@comsoc.org) with your full name, ID number and new postal address. Under no circumstances will scores or pass/fail information be released over the phone or by fax, nor will the information be released to anyone except the candidate.

The score report provides information on whether the candidate passed or failed the examination. In order to pass the examination, candidates must obtain a scale score of 500 or higher on a scale that ranges from 200 to 800. In addition to the scale score, candidates will receive information on the total number of questions in each area of expertise and the number of questions the candidate answered correctly in each area. For passing candidates, the information will help identify specific areas to focus on for continuing education purposes. For failing candidates, this information will identify specific areas where improvement or further study may be required if retaking the examination is a consideration.

Due to the need to maintain test security, examination questions and answers will not be released to candidates.

## Retaking the Examination

Candidates who fail the examination may re-apply for the examination during the next available testing window. Application procedures for those retaking the examination are the same as those for first-time applicants. There is a reduced fee for those taking the exam as a second attempt to pass and for every time subsequent after that.

## Duplicate or Replacement Certificates

Successful candidates who have not received a certificate within three months after the close of the testing window or who receive a damaged certificate should email IEEE ComSoc at [cert@comsoc.org](mailto:cert@comsoc.org). A duplicate certificate (if applicable) will be issued at no cost. A processing and shipping fee may be assessed for requests postmarked more than 90 days after the test date.

If you legally change your name, lose your certificate, or want another certificate for personal reasons, you may request a replacement certificate. To request an additional certificate, email [cert@comsoc.org](mailto:cert@comsoc.org).

Formal name changes require appropriate legal documentation, such as a notarized copy of a marriage certificate or divorce decree. Documentation should be sent to [wcetcertificates@comsoc.org](mailto:wcetcertificates@comsoc.org). A \$75 fee will be required for additional certificates. Payment must be made by VISA, MasterCard, or American Express.

Duplicate certificate requests must include:

- Candidate's full name (as it appears on the application);
- Postal address;
- WCET ID number (found in the Authorization to Schedule notice);
- Examination date; and
- Appropriate legal documentation, if applicable. Please do not send originals, as they cannot be returned.

## Recertification: Renew Your Credential

- Recertification is required after three years for those who certified or renewed their certification in 2015 and later, and after five years for those who certified before 2015
  - By passing the then current exam, or
  - By earning a minimum of 60 or 100 Professional Development Units, as appropriate for the length of the current certification.
- Effective immediately, all new certificates issued will now be valid for a three-year period.
- Successful applicants will receive a certificate with their new certification date.

Recertification is required after three years for those who certified or renewed their certification in 2015 and later, and after five years for those who certified before 2015, as determined by the year the current certification was issued (shown on the individual's current certificate). For example, credential holders who earn their certification in 2017 will need to recertify by 2020. Credential holders who earned their certification in 2014 will need to recertify in 2019. You will have until the Spring or Fall, depending on the date of your certification, of the third or fifth year after you earned your credential to renew your certification. All recertification's are valid for three years. If you have any questions about when your certification is due for renewal, please send an email to [cert@comsoc.org](mailto:cert@comsoc.org).

***There are two ways of earning recertification: by passing the then-current WCET certification exam or by submitting the application showing the earned Professional Development Units (PDUs) through contributions to the profession and/or personal professional development.***

The recertification fee for the three-year period is \$180 for IEEE/ComSoc members and \$210 for non-members. The same fee applies whether you take the certification exam or submit an accounting of PDUs earned since your certification.

### **To Recertify by Passing the Current WCET Certification Exam**

Submit your recertification fee at <http://www.ieee-wcet.org/recertification>. You will then be sent instructions to complete an application and schedule your exam. The exam is updated regularly, and the current exam will test a candidate's knowledge of developments in the field since their previous certification.

### **To Recertify by Submitting the Application Showing the Earned PDUs**

Professional Development Units (PDUs) quantify a candidate's professional and educational or learning activities. PDUs can be earned through participation in activities related to contributions to the profession and/or professional development in the area(s) covered by WCET. Depending on the date of your certification, the Spring deadline to submit PDUs for your recertification is 30 April and the Fall deadline is 31 October. You may apply up to six months before your deadline.

A minimum of 60 PDUs distributed over a three-year recertification cycle, or a minimum of 100 PDUs distributed over a five-year recertification cycle, must be earned during in order to maintain certification. To ensure that the candidate has a broad knowledge of the field, these activities must be related to at least three of the seven areas tested on the WCET examination. See Appendix A for a detailed description of these seven areas.

The following tables outline a variety of ways in which PDUs can be earned and the maximum number of PDUs that can be earned through each activity. Candidates can download an application from [www.ieee-wcet.org/recertification](http://www.ieee-wcet.org/recertification) into which they can enter their information to apply for recertification. The completed application should be submitted to the WCET recertification committee by sending it by email to [wcetre certification@comsoc.org](mailto:wcetre certification@comsoc.org).

All submissions are subject to selection for an audit. If an application is selected for audit, evidence validating the claimed PDUs will be required. Such evidence may include attestation by a candidate's manager regarding work performed, proof of attendance at a training course or conference, or similar verification. A listing of typical documents that may be requested can be accessed at the Recertification page at the WCET website.

***All new certifications will be for a three-year period, in keeping with the accelerating pace of change in the industry and in alignment with numerous other professional certifications.*** Candidates who earned certification/recertification in 2015 or later will recertify after a three-year period and should refer to the table for a three-year cycle to find out how the required 60 PDUs can be earned. Candidates who earned certification/recertification prior to 2015 will recertify after a five-year period and should refer to the table for a five-year cycle to find out how to submit PDUs that provide evidence that they maintained their professional activities throughout the five year certification period.

### Table of PDUs for Recertification after a 3-Year Certification: 60 PDUs Total

**“Contributions to the Profession” include such activities as the following:**

Activity	Description	Maximum PDUs Allowed
Professional Activities	Working in wireless communications <ul style="list-style-type: none"> <li>• Submittal or receipt of a patent</li> <li>• At least 50% of your time spent doing professional level work</li> </ul>	30 PDUs (Up to 10 PDUs/year per three-year cycle for professional-level work. Up to 5 PDUs for a patent application/10 PDUs for a patent awarded with a maximum of 10PDUs for patents).
Professional/ Industry Volunteer Services	<ul style="list-style-type: none"> <li>• ComSoc officer</li> <li>• ComSoc committee membership</li> <li>• Relevant industry standards, conference, or similar committee membership</li> </ul>	20 PDUs (1 PDU per hour of volunteer service up to a maximum of 10 PDUs/year)
WCET Program Support	<ul style="list-style-type: none"> <li>• Writing or reviewing exam questions</li> <li>• Developing a WCET-related tutorial</li> <li>• Contributing to the WEBOK</li> </ul>	15 PDUs (1 PDU/hour of effort)
Course Development/ Instruction	Developing and/or teaching a course in wireless communications; Course development earns twice as many PDUs as teaching.	20 PDUs (1 PDU per hour of teaching; 2 PDUs per hour of course development)
Publications	Publishing relevant technical papers, articles, books, book chapters, etc.	15 PDUs (1 PDU per hour of effort)

**“Professional Development” includes activities such as the following:**

Activity	Description	Maximum PDUs Allowed
Formal Training Programs	Attending relevant live or on-line courses offered by ComSoc or by educational institutions, commercial training providers, and industry organizations or similar.	15 PDUs (1 PDU per hour of study)
Self-Directed Learning	The use of assessment-based self-directed education, such as online tutorials, CDs, DVDs, printed materials, or instructional manuals	10 PDUs (1 PDU per hour of study)
Other Certifications	Acquiring or maintaining a relevant professional license or certification. For example, a Professional Engineer (PE) license (provided the holder is practicing in the field of wireless communications), various state or regulatory body certifications, or other relevant credentials earned through recognized industry/professional organizations.	15 PDUs (1 PDU per hour of effort provided the hours are not claimed elsewhere [e.g., as training])
Industry Conferences and Events	Attending relevant technical sessions, workshops, and/or training activities offered at conferences and other industry events.	15 PDUs (1 PDU per hour of attendance)
Professional/Industrial Community	Attaining a higher level of membership, such as Senior Member or Fellow, in a relevant professional/industrial community.	15 PDUs (PDUs depend on the prior and new member levels)

## Table of PDUs for Recertification after a 5-Year Certification: 100 PDUs Total

**“Contributions to the Profession” include such activities as the following:**

Activity	Description	Maximum PDUs Allowed
Professional Activities	Working in wireless communications <ul style="list-style-type: none"> <li>• Submittal or receipt of a patent</li> <li>• At least 50% of your time spent doing professional level work</li> </ul>	50 PDUs (Up to 20 PDUs for a patent; 6 PDUs/year, to a maximum of 30 per five-year cycle for professional-level work)
Professional/Industry Volunteer Services	<ul style="list-style-type: none"> <li>• ComSoc officer</li> <li>• ComSoc committee membership</li> <li>• Relevant industry standards, conference, or similar committee membership</li> </ul>	30 PDUs (1 PDU per hour of volunteer service up to a maximum of 10 PDUs/year)
WCET Program Support	<ul style="list-style-type: none"> <li>• Writing or reviewing exam questions</li> <li>• Developing a WCET-related tutorial</li> <li>• Contributing to the WEBOK</li> </ul>	25 PDUs (1 PDU/hour of effort)
Course Development/Instruction	Developing and/or teaching a course in wireless communications; Course development earns twice as many PDUs as teaching.	30 PDUs (1 PDU per hour of teaching; 2 PDUs per hour of course development)
Publications	Publishing relevant technical papers, articles, books, book chapters, etc.	25 PDUs (1 PDU per hour of effort)

**“Professional Development” includes activities such as the following:**

Activity	Description	Maximum PDUs Allowed
Formal Training Programs	Attending relevant live or on-line courses offered by ComSoc or by educational institutions, commercial training providers, and industry organizations or similar.	25 PDUs (1 PDU per hour of study)
Self-Directed Learning	The use of assessment-based self-directed education.	15 PDUs (1 PDU per hour of study)
Other Certifications	Acquiring or maintaining a relevant professional license or certification. For example, a Professional Engineer (PE) license (provided the holder is practicing in the field of wireless communications), various state or regulatory body certifications, or other relevant credentials earned through recognized industry/professional organizations.	25 PDUs (1 PDU per hour of effort provided the hours are not claimed elsewhere [e.g., as training])
Industry Conferences and Events	Attending relevant technical sessions, workshops, and/or training activities offered at conferences and other industry events.	20 PDUs (1 PDU per hour of attendance)
Professional/Industrial Community	Attaining a higher level of membership, such as Senior Member or Fellow, in a relevant professional/industrial community.	25 PDUs (PDUs depend on the prior and new member levels)

A relevant course, license, session, or community is one whose principal focus is on one or more aspects of wireless communication. Ideally, the activity will be related to a topic in the examination specifications in Appendix A.

## Appendix A: WCET Examination Specifications

### Major Areas of Expertise

**Area 1 (11-15%) - RF Engineering, Propagation, Antennas, and Signal Processing:** Tasks and knowledge related to: antennas, RF engineering, transmission, reception, propagation, channel modeling, and signal processing.

Evaluate system performance and reliability; calculate path loss; evaluate the effects of different fading and empirical path loss models; calculate and evaluate the effects on the received signal of path-related impairments; determine parameters related to antennas or antenna arrays; generate and evaluate coverage and interference prediction maps; develop and analyze procedure to optimize the coverage of a radio; make RF system measurements.

**Area 2 (19-23%) - Wireless Access Technologies:** Tasks and knowledge related to wireless access networks, especially the physical, MAC, and link layers.

Analyze building blocks, multiple access, mobility management, and spectrum implications in wireless access system design; analyze design considerations to optimize capacity/coverage; design and analyze a wireless access system; analyze the required bandwidth for a wireless system and tradeoffs; analyze wireless access technology standards, their features, and evolution.

**Area 3 (19-23%) - Network and Service Architecture:** Tasks and knowledge related to network infrastructure, including core networks; service frameworks such as IMS; and application architectures such as voice, video streaming, and messaging. All-IP services architecture as in 3GPP Rel 6 and beyond, including Enhanced Packet Services (EPS) as in 3GPP Rel 8 LTE (Long Term Evolution) and EPC (Enhanced Packet Core).

Analyze service platforms, IP addressing schemes for various technologies; design and test quality of service (QoS); select and test a load-balancing scheme; analyze IP routing and ad hoc routing and mesh protocols; perform capacity planning, error tracking, and trace analysis; analyze the evolution of mobile networks to enable IP multimedia.

**Area 4 (19-23%) - Network Management and Security:** Tasks and knowledge related to fault, configuration, account, performance, maintenance, security management, management availability, and operation support systems (examples include network service assurance and provisioning).

Design a fault monitoring system and a performance monitoring system; develop/specify types and methods of alarm reporting; compute availability and reliability metrics; assess the potential impacts of known security attacks; plan corresponding solutions to known security attacks.

**Area 5 (8-12%) - Facilities Infrastructure, Standards and Regulations:** Tasks and knowledge related to the specification, design, implementation, and operation of facilities and sites, and externally imposed compliance requirements and conformance testing, including interoperability.

Determine power consumption; analyze electrical protection requirements and design the electrical protection layout for a wireless telecommunications facility; determine the required antennas for the facility and their positions; develop a specification for the required structure for a wireless base station facility; determine the required cable, antennas, and materials to implement an in-building wireless network; evaluate equipment compliance with industry standards, codes, and site requirements.

Assess service and equipment quality; prepare specifications for purchasing services and equipment and evaluate the responses; verify compliance with regulatory requirements; select and analyze frequency assignments; perform standardized homologation tests as required by regulatory or standardization bodies; evaluate compliance with health, safety, and environmental requirements; perform conformance/interoperability analyses of systems and components; analyze the use of licensed vs. unlicensed spectrum; obtain licenses and permits.

**Area 6 (11-16%) – Emerging New Paradigms and Services:** Tasks and knowledge related to ongoing developments in protocols and architectures for emerging new standards in wireless (5G, 802.11) and service requirements and application scenarios.

Analyze new network and service provisioning architectures (e.g. 5G); emerging standards in W-WAN and W-LAN (especially recent developments of IEEE 802.11); network virtualization and slicing; Internet of Things (IoT); Machine Type Communications (MTC); evolution of the Evolved Packet Core; analyze the evolution of wireless systems to support emerging applications.

**Area 7 (8-12%) - Fundamental Knowledge:** Basic knowledge that a wireless communications engineer would use in order to perform tasks across all domains.

Apply basic concepts related to electrical engineering, communications systems, and general engineering management.

## **Area 1 — RF Engineering, Propagation, Antennas, and Signal Processing**

### **Tasks:**

**T1.01** Calculate link budgets to evaluate system performance and reliability based on received signal level and fade margin (examples might include satellite, microwave link, base station to mobile station, wireless LAN and PAN); calculate path loss for various RF transmission systems (examples might include between isotropic or dipole reference antennas, base station to mobile station, base station to repeater, earth station to satellite, LOS/NLOS paths, and clutter losses).

**T1.02** Calculate the capacity of various multiple-antenna schemes, and analyze the tradeoffs involved in selecting from among alternative schemes (calculations might include analysis of pre-coding techniques).

**T1.03** Evaluate the effects of different fading models (examples might include Rayleigh and lognormal) and empirical path loss models on the received signal strength in various signal propagation environments (examples might include flat terrain, rolling hills, urbanized areas, and indoor environments [such as buildings or tunnels] with losses caused by walls, ceilings, and other obstructions).

**T1.04** Calculate and evaluate the effects on the received signal of path-related impairments, such as Fresnel Zone blockage, delay spread, and Doppler shift of a signal received by a moving receiver.

**T1.05** Calculate the polarization mismatch loss for various antenna systems (examples might include fixed microwave systems, cellular and mobile radio systems, and satellite systems).

**T1.06** Evaluate receive diversity gain for selection, equal gain, and maximal ratio diversity system configurations.

**T1.07** Determine parameters related to antennas or antenna arrays (examples might include pattern, beamwidth, gain, SAR-reduction features, distance from an antenna or array at which far field conditions apply, spacing, beam forming, tilt, and sectorization) and analyze the effects of these parameters on coverage.

**T1.08** Determine appropriate antenna location at base station sites to prevent inter-system and intra-system interference effects, taking into account required radiation patterns and mutual coupling effects.

**T1.09** Generate and evaluate coverage and interference prediction maps (examples might include maps for cellular, mobile radio, and WLAN systems).

**T1.10** Develop and analyze a procedure to optimize the coverage of a radio system using propagation modeling and “drive test” measurements.

**T1.11** Develop a block diagram of an RF system (examples might include cellular, land mobile, and WLAN) employing standard modules (examples might include filters, couplers, circulators, and mixers) and/or using lumped or distributed matching networks, microstrips, and stripline.

**T1.12** Make and analyze RF system measurements (examples might include swept return loss to determine antenna system performance, transmitter output power [peak or average, as appropriate], signal-to-noise ratio at a receiver front end, and co-channel and adjacent-channel interference for specific types of signal spectra).

**Knowledge of:**

**K1.01** different types of losses (examples might include transmission line loss, antenna gain, connector losses, and path loss)

**K1.02** procedures to calculate antenna gain and free space path loss

**K1.03** statistical fading models and distance-power (path loss) relationships in different propagation environments

**K1.04** the effects of outdoor terrain and indoor structures such as walls, floors, and ceilings on signal propagation

**K1.05** common deterministic, statistical, and empirical propagation models (examples might include free space, Okumura, Longley-Rice, and ray-tracing) and software modeling tools (examples might include EDX Signal, ATDI, PathLoss, and similar radio network planning tools) used to implement them

**K1.06** topographical maps and digital terrain databases

**K1.07** indoor and outdoor coverage calculation and verification techniques

**K1.08**  $E_s/N_0$ ,  $E_b/N_0$ , RSSI, NF, and other system parameters

**K1.09** the relationship between receiver noise figure, noise temperature, and receiver sensitivity and the relationship between sensitivity under static conditions and the degradation of effective receiver sensitivity caused by signal fading in different propagation conditions

**K1.10** external noise sources and their impact on the S/N ratios of received signals, and techniques for measuring the impact of external noise

**K1.11** basic antenna system design and use including antenna types (examples might include omnidirectional, panel, parabolic, dipole array, indoor antennas), antenna patterns, gain and EIRP, EIS, ERP, TIS, TRP, antenna size, antenna polarization, receive and transmit diversity, antenna correlation coefficients (examples might include MIMO antenna systems), and proper antenna installation to provide for coverage, interference mitigation, and frequency reuse

**K1.12** adaptive antenna methods and techniques, including null-steering, selection diversity, optimal-ratio combining, adaptive antennas, spatial multiplexing, space-time coding, and MIMO techniques

**K1.13** subscriber unit, mobile, and device antennas and their performance characteristics, including SAR-reduction characteristics

**K1.14** use of test equipment such as network analyzers, spectrum analyzers, and TDRs

**K1.15** co-channel and adjacent channel interference analysis and measurement methods and techniques; multi-user detection and interference-cancellation schemes and their limitations

**K1.16** filters, power dividers, combiners, and directional couplers

**K1.17** signal processing techniques, including matched filtering, adaptive filtering, adaptive equalization, and Rake processing

## **Area 2 — Wireless Access Technologies**

### **Tasks:**

**T2.01** Analyze multiple access schemes for various technologies.

**T2.02** Analyze spectrum implications in wireless access system design (examples might include applications, TDD/FDD, inter-modulation, LOS/NLOS, coverage/capacity).

**T2.03** Analyze design considerations and perform system design to eliminate coverage holes and to optimize capacity/coverage in urban/indoor areas.

**T2.04** Design and analyze a wireless access system (examples might include AP placement and channel selection) according to given bandwidth requirements, coverage, and other considerations.

**T2.05** Test devices with respect to interference issues in various operating environments (examples might include TDMA, CDMA, WCDMA, WLAN, 802.15).

**T2.06** Perform interference analysis (examples: co-site interference in TDMA, CDMA, WCDMA, WLAN, 802.15, and GSM; effect of interference on capacity in cellular, WLAN, WAN, ad hoc and sensor networks).

**T2.07** Compute the required bandwidth for a wireless system given certain network conditions (examples might include BER, flow count, and protocols in use).

**T2.08** Analyze the tradeoffs (examples might include bandwidth versus BER) of various error detection and correction techniques.

**T2.09** Analyze the tradeoffs and capacity implications of mitigation techniques for time-varying channels, including channel estimation; time- and frequency-recovery and tracking; modulation/demodulation; pre-coding; and power control schemes (examples: scheduling algorithms, bandwidth versus power efficiency analysis).

**T2.10** Calculate frequency re-use factor.

**T2.11** Design fundamental elements/attributes of wireless network systems (examples might include cellular, 802.16, WLAN, and satellite).

**T2.12** Analyze the steps involved in the process of handover/handoff for various wireless systems (examples might include UMTS, CDMA2000, 802.16, and WLAN).

**T2.13** Analyze the tradeoff between the size of a paging area and the location update frequency.

### **Knowledge of:**

**K2.01** multiple access and multiplexing schemes (examples might include TDMA, CDMA, OFDMA, FDMA, and SDMA)

**K2.02** technology standards and their evolution (examples might include WCDMA, CDMA2000, LTE, 802.11, 802.15, and 802.16)

**K2.03** error detection and correction, ARQ, HARQ, Turbo Coding, link-adaptation, modulation/demodulation, and pre-coding techniques

**K2.04** objectives of channel-estimation and power-control schemes and their operation

**K2.05** handover/handoff/mobility management, including inter-technology handover/handoff

**K2.06** paging functions

**K2.07** the major components of a wireless network topology

**K2.08** LEOS, MEOS and geostationary satellites, their bands, and their usage for broadcasting

### **Area 3 — Network and Service Architecture**

#### **Tasks:**

**T3.01** Analyze service platforms including service enablers (examples might include messaging, positioning, and location), service creation/delivery (examples might include Open Service Access and Parlay), and service-oriented architecture (SOA). Design and engineer various VAS (CRBT, SMS, VMS, Alerts, etc.) services on wireless network CORE. Design optimum network services for data traffic.

**T3.02** Analyze IP addressing schemes for various technologies (examples might include Mobile IP, ROust Header Compression [ROHC] as in VoIP over HSPA or LTE, IPv4, and IPv6).

**T3.03** Design and test quality of service (QoS) (examples might include design and plan for adequate resources, selecting priority schemes, prioritization of differentiated services, queuing strategies, mapping of QoS classes between network and transport layers and call admission control) for VoIP and IMS-based services. Calculate Capacity and Grade of Service (GOS) for a cellular network e.g., GSM/WCDMA/LTE networks. Provision QoS for different applications per 3GPP standards, e.g. through QCI, ARP, etc. for LTE/EPC networks.

**T3.04** Select and test a load-balancing scheme.

**T3.05** Analyze IP routing (examples might include interpreting an IP routing table).

**T3.06** Analyze ad hoc routing and mesh protocols, and suitability for various deployment scenarios.

**T3.07** Perform capacity planning using traffic engineering principles.

**T3.08** Perform error tracking and trace analysis on protocol control messages for specific systems.

**T3.09** Analyze the evolution of mobile networks to enable IP multimedia services (including circuit-switched to packet-switched network evolution).

**T3.10** Analyze intra- and inter-domain roaming (examples might include roaming within a country or in different countries in 3GPP networks). Analyze service continuity across domains (e.g., VoIP in LTE and circuit-switched voice in GSM/W-CDMA networks).

**T3.11** Analyze the functioning of TCP/IP major transport protocols (examples might include TCP, UDP, and RTP) in the context of wireless communications and limitations of PING/Ack.

**T3.12** Develop a simple block diagram-level design for a network operations center (examples might include digital cellular, web-based mobile content, multimedia broadcast, and SMS).

**Knowledge of:**

**K3.01** IMS (IP multimedia subsystems) and its architecture, including session control and switching plane; knowledge of different VAS in wireless domain

**K3.02** VoIP/IP-multimedia protocols

**K3.03** wireless service enablers evolution, including call processing architecture/framework, feature development/enhancement, as well as applications such as presence, location, etc. policy rules, decisions, charging and enforcement

**K3.04** location and positioning techniques

**K3.05** load balancing principles in the context of wireless communications, and methods to avoid single point of failure through active/active or active standby, and concept of self organizing networks (SON)

**K3.06** IP routing and mobile IP networking and addressing schemes including WLAN systems. IP evolution in wireless access - backhaul and packet core connectivity

**K3.07** error tracking and trace analysis techniques for dropped cells, access failures and other network related problem reports

**K3.08** circuit switched and packet switched data and packet cellular networks and the differences between them; knowledge of various data capable technologies - 1xRTT, EVDO, GPRS/EDGE, LTE

**K3.09** roaming and roaming controls

**K3.10** TCP/IP including transport protocols including WLAN systems

**K3.11** Access Point Name and its functionality

**K3.12** heterogeneous architecture for single-hop and multi-hop wireless networks

## **Area 4 — Network Management and Security**

**Tasks:**

**T4.01** Design a fault monitoring system (examples might include using SNMP TRAP/NOTIFICATION, and using 2G OAM&P standards at Network Element Layer [NEL], Equipment Management Layer [EML], and Network Management Layer [NML]).

**T4.02** Design a performance monitoring system (examples might include using SNMP GET/SET and performance measurement on radio layer, BTS and RNC, usage and traffic analysis and accounting, monitoring SAACH frame error rate in 3GPP networks).

**T4.03** Develop/specify types and methods of alarm reporting for an installation, and other OAM&P.

**T4.04** Compute availability and reliability metrics from both the “network performance” and “system designer” perspectives (related to equipment failure).

**T4.05** Assess the potential impacts of known security attacks on wireless systems (examples might include virus, worm, DoS, network sniffing, flooding and impersonation; additional examples might include SIM/USIM card cloning, attempting bank transaction using prepaid cellular handsets, integrity of SMS, multi subscription of USIM card etc).

**T4.06** Plan corresponding solutions to known security attacks (examples might include stolen SIM card, stolen PIN, use of different handsets using the same SIM card etc).

**T4.07** Monitor, log, and audit security-related data (including tasks such as streaming system logs to third party box for analysis and reporting).

**T4.08** Analyze security vulnerabilities and prepare/recommend corrective actions; develop comprehensive test plan for network security testing.

**T4.09** Design and plan a migration to a new network management scheme (including impacts on OSS, BSS, and billing); design proper access levels (user management) and its implementation.

**T4.10** Analyze wireless accounting and billing schemes including inter-operator accounting.

**T4.11** Design and establish VPN communications from client to host.

**T4.12** Design a secure system using state-of-the-art solutions

**Knowledge of:**

**K4.01** quality of service (QoS) monitoring and control

**K4.02** fault management

**K4.03** configuration management including licensing mechanisms, feature addition/integration, system initialization and installation, policy-based management, role-based access control, level of security offered OTA by standard cellular and wireless systems, and architectures for service management

**K4.04** authentication, authorization, and accounting (AAA) principles and mechanisms and APN security; CAVE, A3/A8 and other authentication algorithms - separating mobile from subscription data; cellular authentication schemes based on HLR, VLR, SIM card

**K4.05** types of security attacks on wireless networks (examples might include use of stolen SIM card, fraudulent techniques to use handsets in non-designated areas)

**K4.06** protocols to secure wireless networks (examples might include Application Security, Web security and Secure Socket Layer, VPN, RADIUS, DIAMETER, HLR/VLR and encryption methods based on cellular algorithms), and Self Organizing/Optimizing networks for next generation networks

**K4.07** security-violation events logging and monitoring, attempts towards billing fraud, SIM card manipulation and detection, etc. and different security testing tools

**K4.08** security issue management and resolution (examples might include management of A-key, OTAP and HLR/VLR updates, monitoring handoff and reauthentication during call)

**K4.09** network management protocols (examples might include simple network management protocol [SNMP], network scanning for BTS identification, interface measurements, data quality measurements, video quality measurements, verification of test mobile phones, acquisition of calibration data for planning tools)

**K4.10** performance metrics pertinent to various access networks (examples might include Carrier to Interface (C/I) matrix; recommended changes to neighbor list to ensure appropriate cell handovers and others)

**K4.11** IP security, Encapsulation Security Payload (ESP), Internet Key Exchange, and digital signature; root authentication keys in removable UIM, Data Subscriber Authentication - DSA over the air interface

**K4.12** MIB, RMON, and Internet Control Messaging Protocol (ICMP)

**K4.13** intrusion detection systems, DDoS attacks, and traceback techniques; GSM security IMSI/TMSI, RAND, SRES-HLR and AuC checking methods, network controlled policies, on-line and off-line charging for pre-paid subscribers

**K4.14** operational process models (examples might include ITIL and eTOM); writing A-key into mobile – manual and over-the-air procedures

**K4.15** hot billing during call, hot billing after call, and similar cases

**K4.16** OTAP (Over the air provisioning methods), USIM (Universal SIM) card architecture, Kasumi security algorithm

**K4.17** mobile money transaction methods, near-field communications and security

**K4.18** knowledge of state-of-the-art network security solutions

## **Area 5 — Facilities Infrastructure, Standards and Regulations**

### **Tasks:**

**T5.01** Determine the power consumption of a unit of communications equipment (examples might include tower amplifier modules, pressurization systems for waveguides).

**T5.02** Determine the power consumption for a facility containing communications equipment (examples might include base station amplifier racks, microwave system rack etc.).

**T5.03** Design a DC power plant to support the facility for a given required reserve time.

**T5.04** Analyze the electrical protection requirements (includes grounding/earthing, bonding, shielding, and lightning protection) and design the electrical protection layout for a wireless telecommunications facility.

**T5.05** Design a wireless communication facility layout plan with considerations for heating, air conditioning, ventilation, and structural issues.

**T5.06** Determine the required antennas for the facility, including specification of the antenna system from RAN to Antenna. Identify and size common types of antenna, amplifiers, and cable for a given scenario.

**T5.07** Determine the required antenna positions on a structure (examples might include towers located in remote/extreme conditions such as mountain tops, arctic areas, etc.).

**T5.08** Design the waveguide/transmission line layout between the communications electronics and the antenna(s).

**T5.09** Coordinate with other users when implementing a communications system in a shared location.

**T5.10** Develop a specification for the required structure for a wireless base station facility based on the required antenna sizes and elevations above ground.

**T5.11** Determine the required cable, antennas, distributed antenna systems, and materials to implement an in-building wireless network.

**T5.12** Determine the required number of racks on which to mount the equipment and the rack layout and placement, taking into account the maintainability of the equipment.

**T5.13** Evaluate equipment compliance with industry standards, codes, and site requirements such as NEBS/ETSI specifications as well as ANSI, IEC, local/city regulations, right of way, and other applicable standards.

**T5.14** Design a site-specific alarm and surveillance system.

**T5.15** Prepare specifications for purchasing services and equipment, and evaluate the responses, including relevant country-specific standards (examples might include preparing request for proposals for introducing new services/licenses and evaluating submitted proposals for implementation of universal services projects).

**T5.16** Verify compliance with regulatory requirements (examples might include licensing, standards, rules, and regulations).

**T5.17** Select and analyze frequency assignments.

**T5.18** Evaluate compliance with health, safety, and environmental requirements.

**T5.19** Perform conformance/interoperability analyses of systems and components, including self organizing and self optimizing networks for NGN.

**T5.20** Analyze the use of licensed vs. unlicensed spectrum.

**T5.21** Obtain and draft licenses and permits where required, including software, hardware, product licenses (open source, GNU, IP, patent laws).

**T5.22** Perform market analysis, study of market indicators, and pricing of telecom services.

#### **Knowledge of:**

**K5.01** procedures to determine the power consumption of wireless communications equipment (examples might include satellite earth station facility, ship/small island based facility, etc.)

**K5.02** how to determine the power required to support a site (examples might include solar and wind based support for tower sites, considerations of bird nests, heated radome, etc.)

**K5.03** the application of AC and DC power systems (examples might include urban towers based on roof tops, tunnels and bridges)

**K5.04** the application of alternative energy sources to wireless communications facilities (examples might include use of solar, wind power, or bio-mass in rural areas)

**K5.05** heating, ventilation, and air conditioning (HVAC) requirements

**K5.06** equipment racks, rack mounting spaces, and related hardware

**K5.07** electrical protection (including grounding/ earthing, bonding, shielding, and lightning protection)

**K5.08** basic waveguides and transmission lines (examples might include elliptical waveguides, multiple cables runs, pressurization and sealing of connectors, etc.)

**K5.09** tower specifications and standards (examples might include wind load calculation based on Effective Plate Area, alignment kits, and elevation angle measurements)

**K5.10** physical security requirements

**K5.11** alarm and surveillance systems

**K5.12** effects of environmental exposure (examples might include corrosion, temperature, and UV susceptibility)

**K5.13** NEBS/ETSI specifications as well as ANSI, IEC, and other applicable standards, codes, and other relevant site-specific requirements

**K5.14** where to find expertise in structural engineering, fire suppression, and other building systems

**K5.15** regulatory requirements and telecom laws (examples might include international, national, and local); emerging standards and network evolution (examples might include convergence of networks, IMT-advanced); regulatory pillars (examples might include transparency, free competition) and mandates (examples might include consumer protection, universal service); international organizations and corresponding structure and functions (examples might include the role of ITU and its subdivisions)

**K5.16** spectrum licensing (examples might include leasing options, primary and secondary assignments in license)

**K5.17** spectrum characteristics, availability, and management including formal methods of measurements to report non-compliance to regulatory bodies

**K5.18** local and site-specific rules/codes (examples might include the National Electric Code in the US and analogous codes in other countries) and engineering regulations (examples might include when engineering work needs to be sealed by a Professional Engineer)

**K5.19** electrical and RF safety (examples might include UL, EC, CSA, and IEEE C.95)

**K5.20** frequency assignment databases and online tools (examples might include verification of registered users in the area, experimental bands and their usages)

**K5.21** health, safety, and environmental issues (examples for RF safety might include SAR limits for different countries [e.g., American limits vs. European limits for accepted SAR-values] and their different ways to measure it)

**K5.22** equipment type approval processes/requirements

**K5.23** how to identify and locate appropriate industry technical standards, applicable codes, and other pertinent requirements

## **Area 6 — Emerging New Paradigms and Services**

### **Tasks:**

**T6.1** Analyze new network and service provisioning architectures

**T6.2** Design, configuration and dimensioning of an 4G LTE and LTE-A system: protocols and architecture

**T6.3** Understand the evolution of cellular networks towards 5G

**T6.4** Design solutions for network virtualization and slicing

- T6.5** Evolution of Wireless WAN and LAN standards: IEEE 802.11, IEEE 802.15, LoRA, etc.
- T6.6** Design of modern WLAN solutions (recent evolutions of IEEE 802.11 beyond ac/ad)
- T6.7** Understand the requirements and deployment scenarios of the Internet of Things (IoT)
- T6.8** Understand the requirements and deployment scenarios of Machine Type Communications (MTC)
- T6.9** Understand the requirements and deployment scenarios of Vehicle Communications (V2X)
- T6.10** Adapt solutions to the evolution of the Evolved Packet Core
- T6.11** Analyze the evolution of cellular wireless systems (RAN and core)
- T6.12** Analyze the evolution of wireless systems to support emerging applications

**Knowledge of:**

- K6.1** Knowledge of 4G LTE and LTE-A protocols and architecture
- K6.2** Knowledge of 5G New Radio standard
- K6.3** Knowledge of the 5G architecture, including network slicing and virtual network functions
- K6.4** Knowledge of application scenarios for wireless networks (IoT, MTC, V2X)
- K6.5** Knowledge of WiFi and its recent evolutions (IEEE 802.11b/a/g, to .11n/ac, to modern versions)
- K6.6** Knowledge of 5G RAN and EPC architectural components and protocols

## **Area 7 — Fundamental Knowledge**

**Knowledge related to electrical engineering**

- K7.1** fundamental AC/DC circuit analysis
- K7.2** mathematics including linear algebra, probability, statistics, and Boolean arithmetic
- K7.3** operation of complex test instruments, including oscilloscopes, spectrum analyzers, network analyzers, TDRs, and signal generators
- K7.4** frequency spectrum and Fourier transforms
- K7.5** basic printed circuit board design considerations
- K7.6** transmission theory and lines, antennas, and basic electromagnetic wave theory and applications
- K7.7** power calculations (examples might include dB, dBm, and dBx)
- K7.8** basic concepts of queuing theory and traffic analysis
- K7.9** basic signal processing (examples: analog and digital processing; quantization; linear filtering theory, concepts, and design)
- K7.10** basic concepts related to optical communications basic electronic system-level block diagrams basic power supply design

**Knowledge related to communication systems**

- K7.13** basic communications and information theory (analog and digital)
- K7.14** basic telephony (including signaling, switching, and transmission)
- K7.15** noise impairments
- K7.16** basic EMI, EMC, and interference
- K7.17** frequency allocations and reuse
- K7.18** modulation techniques for analog (examples might include AM, FM, and PM)
- K7.19** modulation techniques for digital (examples might include FSK, PSK, and QAM)
- K7.20** wireless multiple-access schemes (examples might include FDMA, TDMA, CDMA, and variants)
- K7.21** basic satellite communications
- K7.22** digital data transmission formats (examples might include E1/T1 and OC-n/SDH)
- K7.23** basic components of RF circuitry
- K7.24** basic RF circuit design, including filter design
- K7.25** basic RF coupling, radiation, and antenna theory concepts
- K7.26** measurements for RF circuits and sub systems, such as output power, receiver sensitivity, noise figure, linearity performance, and spectral performance
- Knowledge of general engineering management:**
- K7.27** project management methods and processes
- K7.28** fundamental engineering economics
- K7.29** design and configuration for ease of maintenance
- K7.30** documentation and configuration control schemes
- K7.31** IEEE Code of Ethics

## Appendix B: Suggested References

The following list of suggested references has been created to guide candidates towards the topics that are relevant to wireless technologies covered by the WCET certification examination. The list is, however, not exhaustive; many other useful resources exist and should be considered by applicants studying for the examination. Inclusion on this list is not intended as an endorsement of any book, nor does absence from this list imply anything about the content or utility of any reference. References are listed in alphabetical order by author's name.

### BOOKS

- C.A. Balanis, *Antenna Theory: Analysis and Design*, 4<sup>th</sup> Ed., Wiley, 2016.
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- J. F. Kurose, K. W. Ross, *Computer Networking: A Top-Down Approach*, Pearson, 2016.

### HANDBOOKS

J.D. Gibson, Editor-in-Chief, *The Mobile Communications Handbook (3rd Ed.)*, CRC Press, 2012.

International Telecommunications Union – Radio communication Sector ([www.itu.int/pub/R-HDB](http://www.itu.int/pub/R-HDB))

*Land Mobile Handbook, multiple volumes*

*Satellite Communications Handbook*

National Association of Broadcasters Engineering Handbook (11<sup>th</sup> Edition), Focal Press / NAB, Oct 2017

[http://www.nabstore.com/National\\_Association\\_of\\_Broadcasters\\_Engineering\\_p/9781138930513.htm](http://www.nabstore.com/National_Association_of_Broadcasters_Engineering_p/9781138930513.htm)

### ONLINE RESOURCES

Jong-Moon Chung, *Wireless Communication Emerging Technologies*, MOOC created by Yonsei University (<https://www.coursera.org/learn/wireless-communication-technologies>)

J.P. Linnartz, *Wireless Communication Reference Website, Chapter 3: Wireless Propagation Channels* ([www.wirelesscommunication.nl/reference/chaptr03/propmain.htm](http://www.wirelesscommunication.nl/reference/chaptr03/propmain.htm))

## Appendix C: Sample Examination Questions

The following questions are typical of those that will be used on IEEE WCET certification examinations. An answer key may be found at the end of this Appendix.

1. A mobile terminal moving at a speed of 30 m/sec is receiving a signal with a center frequency of 2 GHz, having a bandwidth of 5 MHz. The received signal has a delay spread of 2  $\mu$ sec. The full Doppler spread of the received signal is approximately:
  1. 0.5 MHz
  2. 200 Hz
  3. 400 Hz
  4. 2.5 MHz
2. In a CDMA cellular system, the coverage region of a cell located in a dense urban environment at 5:00 PM (busy hour) is most likely to be:
  1. The same as the coverage at 3:00 AM (dead hour) because transmit power remains the same.
  2. The same as the coverage at 3:00 AM (dead hour) because propagation remains the same.
  3. smaller than the coverage of 3:00 AM (dead hour) because of higher cell loading.
  4. Smaller than the coverage at 3:00 AM (dead hour) because of more signal fading due to more cars on the street.
3. To overcome the near-far-problem, the CDMA implementation for cellular telephony uses:
  1. Signal spreading.
  2. Power control.
  3. Code word orthogonality.
  4. Frequency re-use.
4. The choice of a duplexing method depends on the:
  1. Chosen multiple access technology.
  2. Nature of the available spectrum and of the traffic in uplink/downlink.
  3. Modulation type and error-correction statistics.
  4. Modulation type and the multiple access technology.
5. Fourth-generation (4G) standards are being developed under the umbrella of the ITU using which of the following names?
  1. IMT-2000 (International Mobile Telecommunications 2000)
  2. FPLMTS (Future Public Land Mobile Telecommunication System)
  3. IMT-Advanced (International Mobile Telecommunications — Advanced)
  4. LTE (Long Term Evolution)

6. In 802.11 using RTS/CTS as an access scheme where the duration of RTS, CTS, and an ACK are all equal to  $T$ , the Short Interframe Spacing duration equals  $S$  and the data packet duration of the transmitting source is  $D$ , the total period allocated to the transmitting terminal and no others is:
  1.  $3T+4S+D$
  2.  $3T+3S+D$
  3.  $3T+S+D$
  4.  $3T+2S+$
7. The relationship among the IEEE 802.11 timing parameters is:
  1.  $SIFS < PIFS < DIFS$ .
  2.  $PIFS < SIFS < DIFS$ .
  3.  $SIFS > PIFS > DIFS$ .
  4.  $SIFS < DIFS < PIFS$ .
8. Consider a receiver with an effective noise temperature of  $33^\circ \text{C}$  (306 K) and a 7-kHz bandwidth. Boltzmann's constant is  $1.38 \times 10^{-23}$  Joules/degree K. The equivalent thermal noise of the receiver input is:
  1.  $-135.3 \text{ dBW}$
  2.  $-173.7 \text{ dBW}$
  3.  $-165.3 \text{ dBW}$
  4.  $-203.7 \text{ dBW}$
9. A fundamental architectural difference between Mobile IPv4 and Mobile IPv6 is that:
  1. Mobile IPv6 does not require Home Agent (HA).
  2. Mobile IPv4 dynamic home agent discovery returns a single reply to the mobile node.
  3. Mobile IPv6 provides secure but less optimized routes than Mobile IPv4.
  4. Mobile IPv6 does not require Foreign Agent (FA).
10. A mobile terminal in a CDMA network transmits a channel with a data rate of 12.2 kbps and has an activity factor of 67%. If the target  $E_b/N_0$  is 5 dB and the chip rate is 3.84 Mcps, the channel's load factor is:
  1.  $1.0 \times 10^{-2}$
  2.  $1.6 \times 10^{-2}$
  3.  $3.2 \times 10^{-3}$
  4.  $6.7 \times 10^{-3}$
11. A communication satellite is operating at 12.75 GHz with EIRP=48 dBW. The ground terminal is 35786 km from the satellite and has a receive antenna with 33.37 dBi gain. The receiver noise temperature is 22.43 dBK. Based on these data, what is the received carrier to noise-spectral density  $C/N_0$ ?
  1. 15.17 dB
  2. 65.28 dB
  3. 81.91 dB
  4. 141.91 dB

12. The maximum Doppler shift of a signal with a carrier frequency of 28 GHz as received by a vehicle moving at 36 km/h is:
  1. 75.6 Hz.
  2. 933 Hz.
  3. 2968 Hz.
  4. Cannot be determined with the given information.
13. Which of the following transmitter antenna systems is the most efficient?
  1. An antenna system that has a return loss of 9.54 dB
  2. An antenna system that has a voltage standing wave ratio of 1.5:1
  3. An antenna system that has a reflection coefficient of 1/3
  4. An antenna system that has a voltage standing wave ratio of 2:1
14. The multiple access method used in Global System for Mobile (GSM) communications standards is:
  1. Orthogonal Frequency Division Multiple Access (OFDMA).
  2. Time Division Multiple Access (TDMA).
  3. Frequency Division Multiple Access (FDMA).
  4. Code Division Multiple Access (CDMA).
15. Bluetooth is an example of a Personal Area Network (PAN) that:
  1. can form a wireless network over a limited distance.
  2. Uses 5.8 GHz frequency band for communication.
  3. Can enable soft handover (i.e., handoff) between two PANs.
  4. Is an essential feature of 3G specification?
16. Universal garage door openers operating in the 30 - 40 MHz are manufactured in Europe. What action should be recommended before the units could be sold in the USA?
  1. To get Underwriter Lab (UL) certification is recommended but not an essential prerequisite.
  2. No action is needed since a universal garage door opener operates over a short range and it operates in an unlicensed band.
  3. A homologation process is needed since ETSI and FCC standards for testing the device do not have a one-to-one correspondence.
  4. Since units are built to metric measurements, verify that they are compatible with the standards of the local distributor.
17. An encryption technique that does NOT rely on the source and destination system sharing the same encryption key is:
  1. Private key encryption.
  2. Secret key.
  3. Public key.
  4. Open key.

18. Radio Jamming attack works at what layer?
1. Physical Layer
  2. Session Layer
  3. Presentation Layer
  4. Network Layer
19. The error protection/recovery strategy most appropriate for a wireless link characterized by poor signal quality and high propagation delay is:
1. Forward error correction.
  2. stop-and-wait ARQ.
  3. Selective repeat ARQ.
  4. go-back-N ARQ.
20. Which one of the following statements best explains the frequency selective fading phenomenon?
1. It arises when the coherence time of the channel is large relative to the delay constraint of the channel.
  2. The coherence bandwidth of the channel is smaller than the bandwidth of the signal.
  3. The coherence bandwidth of the channel is greater than the bandwidth of the signal.
  4. It occurs when the coherence time of the channel is small relative to the delay constraint of the channel.

Answers: Q1 – 3; Q2 – 3; Q3 – 2; Q4 – 2; Q5 – 3; Q6 – 2; Q7 – 1; Q8 – 3; Q9 – 4; Q10 – 4; Q11 – 3; Q12 – 2; Q13 – 2; Q14 – 2; Q15 – 1; Q16 – 3; Q17 – 3; Q18 – 1; Q19 – 1; Q20 – 2

## Appendix D: Glossary

<b>3DES</b>	Triple DES Encryption	<b>ATPC</b>	Automatic Transmit Power Control
<b>3G</b>	3 <sup>rd</sup> Generation Mobile Telecommunications	<b>AuC</b>	Authentication Center
<b>3GPP</b>	3 <sup>rd</sup> Generation Partnership Project	<b>AUT</b>	Antenna Under Test
<b>3GPP2</b>	3G Partnership Project 2	<b>AUTN</b>	Network Authentication Token
<b>A5</b>	Encryption algorithm in GSM	<b>AUTS</b>	Token used in resynchronization
<b>AAA</b>	Authentication, Authorization, and Accounting	<b>AWGN</b>	Additive White Gaussian Noise
<b>AAD</b>	Additional Authentication Data	<b>AWS</b>	Advanced Wireless Services
<b>ACK</b>	Acknowledge	<b>BCCH</b>	Broadcast Control Channel
<b>ACM</b>	Address Complete Message	<b>BCMCS</b>	Broadcast and Multicast Services
<b>ACM</b>	Adaptive Code Modulation	<b>BE</b>	Best Effort
<b>ADC</b>	Analog to Digital Converter	<b>BER</b>	Bit Error Rate
<b>AES</b>	Advanced Encryption Standard	<b>BGP</b>	Border Gateway Protocol
<b>AF</b>	DiffServ Assured Forwarding	<b>BSC</b>	Base Station Controller
<b>AFD</b>	Average Fade Distortion	<b>BSS</b>	Basic Service Set
<b>AGC</b>	Automatic Gain Control	<b>BTS</b>	Base Transceiver Station
<b>ALC</b>	Automatic Level Control	<b>CB</b>	Certification Body
<b>AM</b>	Amplitude Modulation	<b>CBC</b>	Cipher Block Chaining
<b>AMC</b>	Adaptive Modulation and Coding	<b>CBC-MAC</b>	Cipher Block Chaining Message Authentication Code
<b>AMPS</b>	Advanced Mobile Phone System	<b>CC</b>	Call Control
<b>ANM</b>	Answer Message	<b>CCCH</b>	Common Control Channel
<b>ANSI</b>	American National Standards Institute	<b>CCI</b>	Co-Channel Interference
<b>AODR</b>	Ad hoc On Demand Routing	<b>CCM</b>	Counter with CBC-MAC
<b>AP</b>	Access Point	<b>CCMP</b>	Counter with CBC-MAC Protocol
<b>APD</b>	Avalanche Photo Diode	<b>CCSA</b>	China Communications Standards Association
<b>AR</b>	Axial Ratio in Elliptical Polarization	<b>CDMA</b>	Code Division Multiple Access
<b>ARIB</b>	Association of Radio Industries and Businesses	<b>CGM</b>	Conjugate Gradient Method
<b>ARQ</b>	Automatic Repeat-Request	<b>CID</b>	Connection ID
<b>AS</b>	Application Server	<b>CIR</b>	Carrier to Interference Ratio
<b>ASCII</b>	American Standard Code for Information Interchange	<b>CM</b>	Connection Management
<b>ASK</b>	Amplitude Shift Keying	<b>CMOS</b>	Complementary Metal Oxide Semiconductor
<b>ASN</b>	Access Service Network	<b>COFDM</b>	Coded Orthogonal Frequency Division Multiplexing
<b>ASN.1</b>	Abstract Syntax Notation One	<b>COMP128</b>	Authentication Algorithm in GSM
<b>ASP</b>	Application Service Provider	<b>CP</b>	Circular Polarization
<b>ATIS</b>	Alliance for Telecommunications Industry Solutions (US)	<b>CP</b>	Cyclic prefix
<b>ATM</b>	Asynchronous Transfer Mode	<b>CPC</b>	Cyclic Prefix Code
		<b>CQI</b>	Channel Quality Indicator
		<b>CRC</b>	Cyclic Redundancy Check
		<b>CRC-32</b>	Cyclic Redundancy Check, 32 bits

<b>CS</b>	Coding Scheme	<b>DSSS</b>	Direct Sequence Spread Spectrum
<b>CSA</b>	Canadian Standards Association	<b>DVB-H</b>	Digital Video Broadcast - Handheld
<b>CSCF</b>	Call Session Control Function	<b>DWDM</b>	Dense Wavelength Division Multiplexing
<b>CSMA/CA</b>	Carrier Sense Multiple Access with Collision Avoidance	<b>EAP</b>	Extensible Authentication Protocol
<b>CSMA/CD</b>	Carrier Sense Multiple Access with Collision Detection	<b>EAP-FAST</b>	EAP Flexible Authentication via Secure Tunneling
<b>CSN</b>	Connectivity Service Network	<b>EAPoL</b>	EAP over LAN
<b>CST</b>	Computer Simulation Technology	<b>EAP-TLS</b>	EAP Transport Layer Security
<b>CTIA</b>	International Association for the Wireless Telecommunications Industry	<b>EAP-TTLS</b>	EAP Tunneled TLS
<b>CTS</b>	Clear to Send	<b>E-DCH</b>	Enhanced Dedicated Channel
<b>DARPA</b>	Defense Advanced Research Projects Agency	<b>EDGE</b>	Enhanced Data Rates for GSM Evolution
<b>dB<sub>i</sub></b>	Decibel Isotropic	<b>EF</b>	DiffServ Expedited Forwarding
<b>dB<sub>m</sub></b>	Decibel Milliwatts	<b>EGC</b>	Equal Gain Combining
<b>dB<sub>r</sub></b>	Decibel Relative	<b>EGPRS</b>	Enhanced GPRS
<b>DCF</b>	Distributed Coordination Function	<b>EIA</b>	Electronic Industries Alliance
<b>DCH</b>	Dedicated Channel	<b>EIR</b>	Equipment Identity Register
<b>DDoS</b>	Distributed Denial of Service	<b>EM</b>	Electromagnetic
<b>DECT</b>	Digital Enhanced Cordless Telephony	<b>EMC</b>	Electromagnetic Compatibility
<b>DES</b>	Data Encryption Standard	<b>EP</b>	Elliptical Polarization
<b>DiffServ</b>	Differentiated Services	<b>ERP</b>	Effective Radiated Power
<b>DIFS</b>	Distributed Inter-frame Space	<b>ESD</b>	Electrostatic Discharge
<b>DL</b>	Downlink	<b>ESS</b>	Extended Service Set
<b>DMB</b>	Digital Multimedia Broadcasting	<b>ET</b>	Error Tracking
<b>DNS</b>	Domain Name System	<b>eTOM</b>	Enhanced Telecom Operations Map
<b>DoS</b>	Denial of Service	<b>ETSI</b>	European Telecommunications Standards Institute
<b>DPCCH</b>	Dedicated Physical Control Channel	<b>FA</b>	Foreign Agent
<b>DPSK</b>	Differential Phase Shift Keying	<b>FACA</b>	Federal Advisory Committee Act (US)
<b>DQPSK</b>	Differential Quadrature (or Quarternary) Phase Shift Keying	<b>FBSS</b>	Fast Base Station Switching
<b>DRA</b>	Direct Resonator Antenna	<b>FCAPS</b>	Fault Configuration Accounting Performance and Security
<b>DRC</b>	Data Rate Control	<b>FCC</b>	Federal Communications Commission (US)
<b>DS-CDMA</b>	Direct Source Code Division Multiple Access	<b>FDD</b>	Frequency Division Duplex
<b>DSL</b>	Digital Subscriber Line	<b>FDDI</b>	Fiber Distributed Data Interface
<b>DSR</b>	Dynamic Source Routing	<b>FDMA</b>	Frequency Division Multiple Access
<b>DSS1</b>	Digital Subscriber Signaling System No. 1	<b>FDTD</b>	Finite Difference Time Domain
		<b>FEM</b>	Finite Element Method

<b>FFT</b>	Fast Fourier Transform	<b>IBSS</b>	Independent Basic Service Set
<b>FHSS</b>	Frequency Hop Spread Spectrum	<b>ICMP</b>	Internet Control Message Protocol
<b>Fi-Wi</b>	Fiber-Wireless	<b>I-CSCF</b>	Interrogating CSCF
<b>FR 2, 4</b>	Flame Resistant, ANSI Class 2 or 4	<b>ICV</b>	Integrity Check Value
<b>FSK</b>	Frequency Shift Keying	<b>IDEN</b>	Integrated Digital Enhanced Network
<b>FSO</b>	Free Space Optics	<b>IDU</b>	Indoor Unit
<b>FSS</b>	Frequency Selective Surfaces	<b>IEC</b>	International Electrotechnical Commission
<b>G.711</b>	ITU-T Standard for Audio Pulse Code Modulation	<b>IECEE</b>	IEC System for Conformity Testing and Certification of Electrotechnical Equipment and Components
<b>GEO</b>	Geostationary Earth Orbit	<b>IETF</b>	Internet Engineering Task Force
<b>GGSN</b>	Gateway GPRS Support Node	<b>IF</b>	Intermediate Frequency
<b>GKH</b>	Group Key Hierarchy	<b>IFFT</b>	Inverse Fast Fourier Transform
<b>GMSC</b>	Gateway Mobile Switching Center	<b>IK</b>	Integrity Key
<b>GMSK</b>	Gaussian Minimum Shift Keying	<b>IKE</b>	Internet Key Exchange
<b>GPRS</b>	General Packet Radio Service	<b>IMS</b>	IP Multimedia System
<b>GPS</b>	Global Positioning System	<b>IMSI</b>	International Mobile Subscriber Identity
<b>GSM</b>	Global System for Mobile Communications	<b>IMT-2000</b>	ITU Standard: International Mobile Telecommunications for 2000
<b>GTC</b>	Generic Token Card	<b>IP</b>	Internet Protocol
<b>H.263</b>	Low Bit-Rate Video Compression Standard	<b>IP v4</b>	Internet Protocol Version 4
<b>H.264</b>	Next-Generation Video Compression Format (aka MPEG-4 AVC)	<b>IP v6</b>	Internet Protocol Version 6
<b>HA</b>	Home Agent	<b>IP-CAN</b>	IP Connectivity Access Network
<b>HARQ</b>	Hybrid Automatic Repeat Request	<b>IPSec</b>	Internet Protocol Security
<b>HDLC</b>	High-level Data Link Control	<b>IS-95</b>	Interim Standard 95 for CDMA
<b>HE</b>	Home Environment	<b>IS-136</b>	Interim Standard 136 for TDMA
<b>HFSS</b>	High Frequency Structure Simulator	<b>ISAKMP</b>	Internet Security Association and Key Management Protocol
<b>HHO</b>	Hard Handoff	<b>ISDN</b>	Integrated Services Digital Network
<b>Hi-Cap</b>	High Capacity	<b>ISI</b>	Inter-Symbol Interference
<b>HLR</b>	Home Location Register	<b>ISIS</b>	Intermediate System to Intermediate System
<b>HLR/AuC</b>	Home Location Register/Authentication Center	<b>ISM</b>	Industrial, Scientific and Medical Radio Frequency Band
<b>HN</b>	Home Network	<b>ISO</b>	International Organization for Standardization
<b>HO</b>	Handoff	<b>ISUP</b>	ISDN User Part
<b>HSDPA</b>	High Speed Downlink Packet Access	<b>ISUP IAM</b>	ISUP Initial Address Message
<b>HS-DSCH</b>	High Speed Downlink Shared Channel	<b>I-TCP</b>	Indirect TCP
<b>HSPA</b>	High Speed Packet Access		
<b>HSS</b>	Home Subscriber Server		
<b>HSUPA</b>	High Speed Uplink Packet Access		
<b>HTTP</b>	Hypertext Transfer Protocol		

<b>ITIL</b>	Information Technology Infrastructure Library	<b>MIP</b>	Mobile IP
<b>ITU</b>	International Telecommunication Union	<b>MISO</b>	Multiple Input Single Output
<b>ITU-R</b>	ITU Radiocommunication Sector	<b>MM</b>	Mobility Management
<b>ITU-T</b>	ITU Telecommunication Standardization Sector	<b>MMUSC</b>	Multiparty Multimedia User Session Control
<b>KA</b>	Knowledge Area	<b>MoM</b>	Method of Moments
<b>KC</b>	Ciphering Key	<b>MOS</b>	Mean Opinion Score
<b>KCK</b>	EAPoL Key Communication Key	<b>MPDU</b>	MAC Protocol Data Unit
<b>KEK</b>	EAPoL Key Encryption Key	<b>MPEG</b>	Moving Picture Expert Group
<b>LAN</b>	Local Area Network	<b>MPLS</b>	Multiprotocol Label Switching
<b>LDPC</b>	Low-Density Parity Check	<b>MR</b>	Mesh Router
<b>LEO</b>	Low Earth Orbit	<b>MRC</b>	Maximum Ratio Combining
<b>LHCP</b>	Left Hand Circular Polarization	<b>MRF</b>	Media Resource Function
<b>LMS</b>	Least Mean Square	<b>MS</b>	Mobile Station
<b>LO</b>	Local Oscillator	<b>MSC</b>	Mobile Switching Center
<b>Lo-Cap</b>	Low Capacity	<b>MSC/VLR</b>	MSC Visitor Location Register
<b>LOS</b>	Line Of Sight	<b>MSK</b>	Minimum Shift Keying
<b>LP</b>	Linear Polarization	<b>MSS</b>	Maximum Segment Size
<b>LR-WPAN</b>	Low Rate Wireless Personal Area Network	<b>MTBF</b>	Mean Time Between Failures
<b>LS-CMA</b>	Least Squares Constant Modulus Algorithm	<b>MTTR</b>	Mean Time To Repair
<b>LTE</b>	Long Term Evolution	<b>MU-MIMO</b>	Multiple User MIMO
<b>MAC</b>	Medium Access Control	<b>NACK</b>	Negative Acknowledge
<b>MAC</b>	Message Authentication Code	<b>NAS</b>	Network Access Server
<b>MAC-S</b>	Authentication Token Used in Resynchronization	<b>NAV</b>	Network Allocation Vector
<b>MAN</b>	Metropolitan Area Network	<b>NCRP</b>	National Council on Radiation Protection & Measurements
<b>MAP</b>	Mobile Application Part	<b>NEBS</b>	Network Equipment-Building System
<b>MBMS</b>	Multimedia Broadcast/Multicast Service	<b>NEC</b>	National Electrical Code (NFPA 70)
<b>MCW</b>	Multi Codeword	<b>NF</b>	Noise Figure
<b>MD5</b>	Message Digest 5	<b>NFC</b>	Near Field Communication
<b>MDHO</b>	Macro Diversity Handover	<b>NGMC</b>	Next Generation Mobile Committee
<b>MDS</b>	Minimum Discernible Signal	<b>NGMN</b>	Next Generation Mobile Network
<b>Media-FLO</b>	Forward Link Only Data Transmission	<b>NGN</b>	Next Generation Network
<b>MGCF</b>	Media Gateway Control Function	<b>NIC</b>	Network Interface Card
<b>MGW</b>	Media Gateway	<b>NIST</b>	National Institute of Standards and Technology (US)
<b>MIB</b>	Management Information Base	<b>NLOS</b>	Non Line Of Sight
<b>MIC</b>	Message Integrity Code	<b>NMHA</b>	Normal Mode Helical Antenna
<b>MIMO</b>	Multiple Input Multiple Output	<b>NRSC</b>	National Radio Systems Committee
		<b>NRSC</b>	Network Reliability Steering Committee (ATIS – US)
		<b>NRZ</b>	Non-Return to Zero

<b>NSP</b>	Network Service Provider	<b>PSK</b>	Phase Shift Keying
<b>NSS</b>	Network Subsystem	<b>PSTN</b>	Public Switched Telephone Network
<b>NSTAC</b>	National Security Telecommunications Advisory Committee (US)		
		<b>QAM</b>	Quadrature Amplitude Modulation
		<b>QoS</b>	Quality of Service
		<b>QPSK</b>	Quadrature Phase Shift Keying
<b>OATS</b>	Open Area Test Site	<b>RAB</b>	Radio Access Bearer
<b>ODU</b>	Outdoor Unit	<b>RACH</b>	Random Access Channel
<b>OFDM</b>	Orthogonal Frequency-Division Multiplexing	<b>RADIUS</b>	Remote Access Dial In User Server
<b>OFDMA</b>	Orthogonal Frequency Division Multiple Access	<b>RAN</b>	Radio Access Network
<b>OGC</b>	Office of Government Commerce (UK)	<b>RAND</b>	Random
<b>OLSR</b>	Optimized Link State Routing	<b>RC4</b>	RC4 Cipher Algorithm
<b>OSA</b>	Opportunistic Spectrum Address	<b>RET</b>	Remote Electrical Tilt
<b>OSI</b>	Open Systems Interconnection	<b>RF</b>	Radio Frequency
<b>OSPF</b>	Open Shortest Path First	<b>RFC</b>	Request for Change
<b>OSS/BSS</b>	Operational and Business Support Systems	<b>RFC</b>	Request for Comments
<b>OTA</b>	Over The Air	<b>RFID</b>	Radio Frequency Identification
<b>OTP</b>	One Time Password	<b>RHCP</b>	Right Hand Circular Polarization
		<b>RIP</b>	Routing Information Protocol
<b>PA</b>	Power Amplifier	<b>RLC</b>	Radio Link Control
<b>PAN</b>	Personal Area Network	<b>RLS</b>	Recursive Least Squares
<b>PAPR</b>	Peak to Average Power Ratio	<b>RMON</b>	Remote Network MONitoring
<b>PBCCH</b>	Packet Broadcast Control Channel	<b>RNC</b>	Radio Network Controller
<b>PCM</b>	Pulse Code Modulation	<b>ROAMOPS</b>	IETF Roaming Operations
<b>P-CSCF</b>	Proxy CSCF	<b>ROF</b>	Radio Over Fiber
<b>PDC</b>	Personal Digital Cellular	<b>ROHC</b>	RObust Header Compression
<b>PDSN</b>	Packet Data Serving Node	<b>RR</b>	Radio Resource
<b>PDU</b>	Protocol Data Unit	<b>RRC</b>	Radio Resource Control
<b>PEAP</b>	Protected EAP	<b>RSA</b>	Rivest, Shamir, and Adelman algorithm for cryptography
<b>PHY</b>	Physical (layer)	<b>RSN</b>	Robust Security Network
<b>PIFA</b>	Planar Inverted F Antenna	<b>RSNA</b>	Robust Security Network Association
<b>PIN</b>	Personal Identification Number	<b>RTP</b>	Real Time Protocol
<b>PIN</b>	Positive Intrinsic Negative (photodiode)	<b>RTS</b>	Request To Send
<b>PKH</b>	Pairwise Key Hierarchy	<b>RTT</b>	Round Trip Time
<b>PL</b>	Path Loss	<b>S/N</b>	Signal to Noise Ratio
<b>PLMN</b>	Public Land Mobile Network	<b>SA</b>	Security Association
<b>PN</b>	Pseudo Noise	<b>SAR</b>	Specific Absorption Rate
<b>PO</b>	Physical Optics	<b>SCCP</b>	Signaling Connection Control Protocol
<b>PON</b>	Passive Optical Network	<b>SCP</b>	Smart Card Platform (ETSI)
<b>PPP</b>	Point to Point Protocol	<b>S-CSCF</b>	Serving CSCF
<b>PRMA</b>	Packet Reservation Media Access		

<b>SCTP</b>	Stream Control Transmission Protocol	<b>TCH/FS</b>	Traffic Channel Full Rate Speech
<b>SCW</b>	Single Codeword	<b>TCH/HS</b>	Traffic Channel Half Rate Speech
<b>SDCCH</b>	Stand-alone Dedicated Control Channel	<b>TCP</b>	Transmission Control Protocol
<b>SDH</b>	Synchronous Digital Hierarchy	<b>TCP/IP</b>	TCP/Internet Protocol
<b>SDMA</b>	Space Division Multiple Access	<b>TD-CDMA</b>	Time Division CDMA
<b>SDR</b>	Software Defined Radio	<b>TDD</b>	Time Division Duplex
<b>SEGF</b>	Security Gateway Function	<b>TDD-HCR</b>	TDD High Chip Rate
<b>SET</b>	Secure Electronic Transaction	<b>TDD-LCR</b>	TDD Low Chip Rate
<b>SF</b>	Spreading Factor	<b>TDMA</b>	Time Division Multiple Access
<b>SFDR</b>	Spurious Free Dynamic Range	<b>TDOA</b>	Time Difference Of Arrival
<b>SFID</b>	Service Flow ID	<b>TD-SCDMA</b>	Time Division Synchronous CDMA
<b>SGSN</b>	Serving GPRS Support Node	<b>TIA</b>	Telecommunications Industry Association
<b>SGW</b>	Signaling Gateway	<b>TK</b>	Temporal Key
<b>SHA</b>	Secure Hash Algorithm	<b>TKIP</b>	Temporal Key Integrity Protocol
<b>SID</b>	Secure Identification Number	<b>TMF</b>	TeleManagement Forum
<b>SIFS</b>	Short Inter-Frame Space	<b>TRAP</b>	TDMA-based Randomly Accessed Polling
<b>SIG</b>	Special Interest Group (of WWRF)	<b>Triple DES</b>	Triple DES Encryption (3DES)
<b>SigTran</b>	Signal Transport	<b>TS</b>	Time Slot
<b>SIM</b>	Subscriber Identity Module	<b>TSC</b>	TKIP Sequence Counter
<b>SIMO</b>	Single Input Multiple Output	<b>TSG</b>	3 GPP Technical Specification Group
<b>SIP</b>	Session Initiation Protocol	<b>TSG CT</b>	Core Network and Terminals TSG
<b>SIR</b>	Signal to Interference Ratio	<b>TSG</b>	GSM EDGE Radio Access Network TSG
<b>SISO</b>	Single Input Single Output	<b>GERAN</b>	TSG
<b>SLF</b>	Subscriber Location Function	<b>TSG RAN</b>	Radio Access Network TSG
<b>SMI</b>	Structure of Management Information	<b>TSG SA</b>	Service & Systems Aspects TSG
<b>SMS</b>	Short Message Service	<b>TTA</b>	Telecommunications Technology Association of Korea
<b>SM-SC</b>	Short Message Service Center	<b>TTC</b>	Telecommunication Technology Committee (Japan)
<b>SMTP</b>	Simple Message Transfer Protocol	<b>TWTA</b>	Traveling Wave Tube Amplifier
<b>SNMP</b>	Simple Network Management Protocol	<b>UDP</b>	User Datagram Protocol
<b>SNR</b>	Signal to Noise Ratio	<b>UE</b>	User Equipment
<b>SPC</b>	Single Parity Check	<b>UL</b>	Underwriters Laboratories (US)
<b>SQN</b>	Sequence Number	<b>UMB</b>	Ultra Mobile Broadband
<b>SRES</b>	Signed Response	<b>UMTS</b>	Universal Mobile Telecommunications System
<b>SRTP</b>	Secure RTP	<b>UMTS AKA</b>	UMTS Authentication and Key Agreement
<b>SS7</b>	Signaling System No. 7	<b>UPC</b>	Uplink Power Control
<b>SSB</b>	Single Sideband	<b>UPS</b>	Uninterruptible Power Supply
<b>SSID</b>	Service Set Identifier	<b>USGS</b>	United States Geological Survey
<b>SSPA</b>	Solid State Power Amplifier	<b>USIM</b>	UMTS SIM
<b>STA</b>	Station		
<b>STM</b>	Synchronous Transfer Mode		
<b>SYN</b>	Synchronization		
<b>TCH</b>	Traffic Channel		

<b>UTRA</b>	UMTS Terrestrial Radio Access	<b>WINNER</b>	Wireless World Initiative New Radio
<b>UTRAN</b>	UMTS Terrestrial Radio Access Network	<b>WLAN</b>	Wireless Local Area Network
<b>UWB</b>	Ultra Wideband	<b>WMAN</b>	Wireless Metropolitan Area Network
<b>VLR</b>	Visitor Location Register	<b>WMN</b>	Wireless Mesh Network
<b>VN</b>	Visited Network	<b>WPA</b>	WiFi Protected Access
<b>VoIP</b>	Voice over Internet Protocol	<b>WPAN</b>	Wireless Personal AreaNetwork
<b>VSAT</b>	Very Small Aperture Terminal	<b>WRC</b>	World Radiocommunication Conference
<b>VSWR</b>	Voltage Standing Wave Ratio	<b>WWRF</b>	Wireless World Research Forum
<b>WAN</b>	Wide Area Network	<b>XG</b>	Next Generation
<b>W-CDMA</b>	Wideband CDMA	<b>XKMS</b>	XML Key Management Services
<b>WCET</b>	Wireless Communication Engineering Technologies	<b>XMAC</b>	Cryptographic primitive in the 3GSM Key Generation Process
<b>WCP</b>	Wireless Communications Professional	<b>XOR</b>	Exclusive Or
<b>WEP</b>	Wireless Encryption Protocol	<b>ZRP</b>	Zone Routing Protocol
<b>WERT</b>	Wireless Emergency Response Team		
<b>WG</b>	Working Group (e.g., of WWRF)		
<b>WiFi</b>	Wireless Fidelity		
<b>WiMAX</b>	Worldwide Interoperability for Microwave Access		

## Appendix E: Constants, Conversions and Equations

### Constants and Conversions

Boltzmann's constant:  $k = 1.38 \times 10^{-23}$  Joules/Kelvin

Speed of light:  $c = 3 \times 10^8$  meters/second

Radius of the earth:  $R = 6,367$  km

Natural log base:  $e = 2.718$

Log base conversion:  $\log_2(x) = (\ln x)/(\ln 2) \approx 1.443 \ln x$

### Equations

Radiowave propagation in free space: 
$$\frac{P_r}{P_t} = G_t G_r \left( \frac{\lambda}{4\pi d} \right)^2$$

Total path loss: 
$$L_{tot}(d) = \left( \frac{\lambda}{4\pi d_0} \right)^2 \times \left( \frac{d_0}{d} \right)^n$$

Approximate LOS distance to the radio horizon  
with  $d$  given in km and  $h$  in meters: 
$$d \approx \sqrt{17h}$$

LOS clearance above an obstacle (metric) with  
 $d_1$  and  $d_2$  in km,  $F$  in GHz, and  $R$  in meters: 
$$R = 17.3 \sqrt{\frac{d_1 d_2}{F(d_1 + d_2)}}$$

Wavelength:  $\lambda = c/f$

Maximum Doppler frequency shift:  $f_m = v/\lambda$

Level-crossing rate (Rayleigh fading):  $N_R = \sqrt{2\pi} f_m \rho e^{-\rho^2}$

Average fade duration (Rayleigh fading):  $\bar{\tau} = \frac{e^{\rho^2} - 1}{\rho f_m \sqrt{2\pi}}$

Erlang B distribution:  $P = \frac{A^C / C!}{\sum_{k=0}^C A^k / k!}$

Channel capacity:  $C = W \log_2 \left( 1 + \frac{S}{N} \right)$

### Antenna Design Equations

Antenna gain:  $G = DE_{ant} = D \frac{R_{rad}}{R_{rad} + R_{loss}}$

Parabolic antenna directivity:  $D = \varepsilon_{ap} \left( \frac{2\pi r}{\lambda} \right)^2$

Near/far-field boundary:  $R = \frac{2L^2}{\lambda}$

### Noise Figure Calculations

$$F_{sys} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \dots$$

## About the IEEE Communications Society

The IEEE Communications Society is a diverse group of industry professionals with a common interest in advancing all communication technologies. Individuals within this unique community interact across international and technological borders to produce publications, organize conferences, foster educational programs, promote local activities, and work on technical committees. Website: **[www.comsoc.org](http://www.comsoc.org)**

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Leading organizations around the world have found that it pays to invest in professional credentialing. The IEEE Wireless Communications Professional (WCP) credential is designed to have high pay-off for your organization and for the wireless communications industry.

- IEEE WCP credential holders have demonstrated their knowledge of wireless engineering technology concepts and terminology. To obtain the IEEE WCP credential, candidates must pass a rigorous examination based on the validated body of knowledge underlying the tasks performed in the industry.
- IEEE WCP credential holders are applied practitioners. Credential holders are tested not only on their knowledge of wireless communication engineering technology and practice, but also on their skills using that knowledge to perform and to develop and implement high-quality deliverables.
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— *Vasu Subramanian, Manager, Alcatel-Lucent*

“The exam truly tested the broader understanding of the wireless engineering profession ...”

— *Sivan Ramanchandran, Bangalore, India*

“The WCET certification greatly helps to communicate my capabilities to others.”

— *Chris Barroso, San Diego, California*

“... We do not often come across a program which specifically addresses the full breadth of this technology nor the aspirations of wireless engineers in gaining recognized and specific industry qualifications through a program of study and learning outside of their college or degree courses.”

— *Ian Rose, BT Design, United Kingdom*