Is the polygraph test accurate

Polygraph exams are designed to measure physiological responses associated with deception, such as respiration, heart rate, blood pressure, and skin conductivity. The tests are typically used in law enforcement to prove whether or not the examinee has committed a crime. Besides, they're administered by numerous companies during employee recruitment procedures to validate job applicants' claims. Since polygraph evaluations can put the defendant's reputation (and sometimes their life) on the line, they must attain the highest possible accuracy score. But just how precise are lie detector tests in detecting deception? Let's find out. In 2010, the American Polygraph Association (APA) unveiled standards that require polygraph techniques deployed in specific testing situations to attain an accuracy score of at least 90% to be validated. These requirements have been widely disputed, with some reviewers putting the accuracy score as low as 64%. Either way, many lie detector tests continue to fall short of the industry's benchmarks. Some polygraph exams are also riddled with fraudulent allegations, casting more aspersions on their credibility. The reality is that lie detector tests can vary in accuracy, depending on several psychological and physical factors. A polygraph examinee's psychological disposition can impact the test's accuracy. For instance, stress and anxiety may affect certain physiological responses like heart rate, potentially leading to false positives or negatives. Certain ailments and medications can impact the accuracy of lie detector tests. That's especially true for conditions/drugs that impair the autonomous nervous system (ANS), such as Parkinson's disease, alcohol use disorder (AUD), nicotine, and cholinesterase inhibitors. Polygraphs administered by qualified examiners typically deliver higher accuracy scores. A professional examiner will follow proper question design rules, prepare the defendant adequately for the exam, and conduct the test using industry-approved techniques.Opinion remains sharply divided on the accuracy of polygraph tests. Advocates hold that since polygraph tests assess physiological responses synonymous with lying, their credibility is beyond reproach as long as they're administered by a qualified examiner. They add that even in the presence of mitigating factors, professional examiners can still deliver accurate results by gauging the responses against predefined physiological baselines. However, polygraph skeptics take issue with the fact that these tests lack solid scientific backing. Critics particularly cite the Daubert ruling of 1993, in which the Supreme Court spelled out four preconditions for the legal admissibility of evidence as follows; Practicality – A theory/technique must have been tried and tested Evaluation – A theory/technique must be peer-reviewed and published Accuracy – A theory/technique must be proven or reasonably believed to be highly accurate Application – A theory/technique must be applied in its relevant scientific fieldFurther, critics hold that jurors are professionally equipped to gauge the credibility of defendants or witnesses with or without lie detector results. In a case study examining the accuracy of polygraph tests, researchers validated common assertions that lie detector tests are remarkably accurate if professionally administered. However, they noted that polygraph exams were vulnerable to inaccuracies in subjects with autonomic dysfunctions. This underscores the significance of establishing an examinee's baselines before subjecting them to a polygraph test.To enhance the accuracy of lie detector tests, examiners must apply standardized testing procedures. That entails subjecting the defendant to pre-test interviews, the in-test phase, and the post-test interviews. Besides, polygraph questions must be probative of the subject under investigation and not wildly ambiguous.An examiner's experience and training also play a critical role in influencing the accuracy of lie detector tests. In addition to receiving professional training from an APA-accredited school, an aspiring polygrapher must obtain practical experience through an internship and be a member of reputable polygraph networks. It's also worth noting that unilaterally obtained polygraph exam results are almost always inadmissible. The tests are only deemed credible if both parties (polygrapher and examinee) agree. Moreover, there's a need for proper application of control questions and experience in detecting countermeasures. Control questions enable polygraph examiners to detect deception by asking general questions about the subject's past misdeeds. The idea is to elicit physiological responses so polygraphers can gauge those reactions against responses to questions on the actual crime under investigation. Despite applying control questions, deceptive characters will always attempt to beat polygraphs by deploying countermeasures (such as drugs and biofeedback techniques). A polygrapher must be well-equipped to professionally challenge these countermoves.Six reviews of previous scientific studies found that polygraph exams have an accuracy score between 64 and 98%. Multiple factors account for the variance, including the defendant's physiological and psychological baselines, the examiner's experience, and the general polygraph techniques used. Since polygraph test results are legally admissible in several states and various non-legal fields, examiners must pull all the stops to ensure each test achieves the highest score possible. Getty ImagesThere are calls for Brett Kavanaugh to take a lie detector test as part of an investigation into alleged sexual misconductIn a secure basement room of the US Capitol building, senators are reading a secretive FBI report into allegations of sexual misconduct made against Supreme Court nominee Brett Kavanaugh.The contents of the report are not meant to be revealed, and there has been some criticism that the scope of the investigation has not been wide enough.Throughout the investigation senior Democrats have called for Mr Kavanaugh to take a lie detector test. One of his accusers, Christine Blasey Ford, has already done so.But how accurate are these tests? And do they work? Let's start with the basics...What is a polygraph test?In short, polygraph tests record a number of different bodily responses which can then be used to determine whether someone is telling the truth.They usually measure things like blood pressure, changes in a person's breathing, and sweating on the palms."The polygraph, like any other lie detection technique, measures an indirect effect of lying," says Dr Sophie van der Zee, who has expertise in forensic psychology and has researched deception for many years."There's no human equivalent of Pinocchio's nose," she says. "But lying can increase stress... and with lie detection techniques you can measure the behavioural and physiological changes that occur when you feel stress."So polygraph tests do not measure deception or lying directly, but rather possible signs that a person could be deceiving the interviewer.This information is then used in conjunction with everything else that is known about the person to form a clearer picture of whether or not they are being truthful.How are they carried out?Polygraphs have been used around the world, in countries such as Japan, Russia and China, but the technology remains largely the same."There's a fairly long pre-test interview that lasts for about an hour," says Prof Don Grubin, who has trained polygraph examiners in the UK. "This focuses the individual on the questions they're going to be asked and tries to remove any outside distractions."This is followed by a practice test, which usually involves a number of straightforward questions. The aim is to relax the individual so they are comfortable and able to understand how the process works.Science Photo LibraryPolygraphs measure blood pressure, changes in a person's breathing, and sweating"There are no surprise questions because that in itself will trigger a response," Prof Grubin says. "What you're going to be asked is known."The equipment is then attached, and it usually includes a blood pressure monitor, electrodes which are placed on the fingers or palm, and two tubes which are wrapped around the chest and stomach."There may be something that's put on the tip of the finger that records blood flow and we also use something called a movement detector which is on the seat and picks up if you're trying to beat the test," Prof Grubin explains."You'll probably be attached to the equipment for 10-15 minutes but you'll be in the room for about two hours," he says.Interviewers ask a number of control questions during the test and then compare the responses to the key questions. It finishes with a post-test interview, where the person will be able to explain any responses they showed.The curious history of the lie detectorCan you cheat?Yes, according to the experts."There's no question that you can beat a polygraph test but you really need the training to do it," says Prof Grubin. "You see websites telling you how to, but the reality is if you just go in and take a polygraph while hoping to beat it then you're not going to."He says that it requires sitting down and practising with a trained examiner. But for those who don't have a qualified questioner to hand - what methods can work?"You might put a tack in your shoe which will cause, for example, a big increase in your sweating response," Prof Grubin says. "Any sort of muscular activity or movement because you need to sit still.""There are various drugs that people try but they tend not to be successful," he adds.But he cautions that most examiners will be able to spot any covert attempt to beat the test. Polygraph tester Deepti Puranaik put the BBC's Rajini Vaidyanathan through a lie detector testSo does this work?The credibility of the polygraph was challenged almost as soon as it was invented in 1921, and there is much debate about its accuracy.Some experts say the fundamental premise is flawed."It does not measure deception, which is the core problem," says Prof Aldert Vrij, who has written extensively on the subject. "The idea is that liars will show increased arousal when answering the key questions, whereas truth tellers will not."But there is no sound theory to back this up."Dr van der Zee says that, because taking a lie detector test can be a stressful experience, it can sometimes present innocent people as guilty."People being interviewed with a polygraph are likely to feel stressed. So whilst the polygraph is quite good at identifying lies, it is not very good at identifying truths," she says.Getty ImagesWashington officials experimenting with an early polygraph in 1922But Prof Grubin says there are a number of different reasons why a test may be inaccurate. These include the questions being poorly formulated and the interviewer misreading the results."If the examiner is well-trained, if the test is properly carried out, and if there's proper quality controls, the accuracy is between 80%-90%," he says, adding that this is higher than the average person's ability to tell if someone is lying.However, he says that interviewing victims presents a separate problem."Testing victims is a whole different ball game because of the nature of what you're being asked about, you would expect a lot of arousal anyway," he says.This means a victim, especially one recovering from a traumatic experience, may appear as if they are lying because they are in an emotional state.Ultimately, experts say there are many caveats to polygraphs and a number of different factors which can lead to an inaccurate result. Pseudoscientific device that attempts to infer lying For other uses, see Polygraph (disambiguation). "Lie Detector" redirects here. For other uses, see Lie Detector (disambiguation). American inventor Leonarde Keeler tested his improved polygraph on Arthur Koehler, a former witness for the prosecution at the 1935 trial of Richard Hauptmann A polygraph, often incorrectly referred to as a lie detector test,[1][2][3] is a pseudoscientific[4][5][6] device or procedure that measures and records several physiological indicators such as blood pressure, pulse, respiration, and skin conductivity while a person is asked and answers a series of questions.[7] The belief underpinning the use of the polygraph is that deceptive answers will produce physiological responses that can be differentiated from those associated with non-deceptive answers; however, there are no specific physiological reactions associated with lying, making it difficult to identify factors that separate those who are lying from those who are telling the truth.[8] In some countries, polygraphs are used as an interrogation tool with criminal suspects or candidates for sensitive public or private sector employment. Some United States law enforcement and federal government agencies, as well as many police departments, use polygraph examinations to interrogate suspects and screen new employees. Within the US federal government, a polygraph examination is also referred to as a psychophysiological detection of deception examination.[11] Assessments of polygraphy by scientific and government bodies generally suggest that polygraphs are highly inaccurate, may easily be defeated by countermeasures, and are an imperfect or invalid means of assessing truthfulness.[12][13][6][14] A comprehensive 2003 review by the National Academy of Sciences of existing research concluded that there was "little basis for the expectation that a polygraph test could have extremely high accuracy."[6] The American Psychological Association states that "most psychologists agree that there is little evidence that polygraph tests can accurately detect lies."[8] For this reason, the use of polygraph tests to detect lies is considered a form of pseudoscience, or junk science.[15] See also: Lie detection § Questioning and testing techniques The examiner typically begins polygraph test sessions with a pre-test interview to gain some preliminary information which will later be used to develop diagnostic questions. Then the tester will explain how the polygraph is supposed to work, emphasizing that it can detect lies and that it is important to answer truthfully. Then a "stim test" is often conducted: the subject is asked to deliberately lie and then the tester reports that he was able to detect this lie. Guilty subjects are likely to become more anxious when they are reminded of the test's validity. However, there are risks of innocent subjects being equally or more anxious than the guilty.[16] Then the actual test starts. Some of the questions asked are "irrelevant" ("Is your name Fred?"), others are "diagnostic" questions, and the remainder are the "relevant questions" that the tester is really interested in. The different types of questions alternate. The test is passed if the physiological responses to the diagnostic questions are larger than those during the relevant questions.[17] Criticisms have been given regarding the validity of the administration of the Control Question Technique. The CQT may be vulnerable to being conducted in an interrogation-like fashion. This kind of interrogation style would elicit a nervous response from innocent and guilty suspects alike. There are several other ways of administering the questions. An alternative is the Guilty Knowledge Test (GKT), or the Concealed Information Test, which is used in Japan.[19] The administration of this test is given to prevent potential errors that may arise from the questioning style. The test is usually conducted by a tester with no knowledge of the crime or circumstances in question. The administrator tests the participant on their knowledge of the crime that would not be known to an innocent person. For example: "Was the crime committed with a .45 or a 9 mm?" The questions are in multiple choice and the participant is rated on how they react to the correct answer. If they react strongly to the guilty information, then proponents of the test believe that it is likely that they know facts relevant to the case. This administration is considered more valid by supporters of the test because it contains many safeguards to avoid the risk of the administrator influencing the results.[20] Assessments of polygraphy by scientific and government bodies generally suggest that polygraphs are inaccurate, may be defeated by countermeasures, and are an imperfect or invalid means of assessing truthfulness.[6][12][13] Despite claims that polygraph tests are between 80% and 90% accurate by advocates,[21][22] the National Research Council has found no evidence of effectiveness.[13][23] In particular, studies have indicated that the relevant–irrelevant questioning technique is not ideal, as many innocent subjects exert a heightened physiological reaction to the crime-relevant questions.[24] The American Psychological Association states "Most psychologists agree that there is little evidence that polygraph tests can accurately detect lies."[8] In 2002, a review by the National Research Council found that, in populations "untrained in countermeasures, specific-incident polygraph tests can discriminate lying from truth telling at rates well above chance, though well below perfection". The review also warns against generalization from these findings to justify the use of polygraphs—"polygraph accuracy for screening purposes is almost certainly lower than what can be achieved by specific-incident polygraph tests in the field"—and notes some examinees may be able to take countermeasures to produce deceptive results.[25] In the 1998 US Supreme Court case United States v. Scheffer, the majority stated that "There is simply no consensus that polygraph evidence is reliable [...] Unlike other expert witnesses who testify about factual matters outside the jurors' knowledge, such as the analysis of fingerprints, ballistics, or DNA found at a crime scene, a polygraph expert can supply the jury only with another opinion." The Supreme Court summarized their findings by stating that the use of polygraph was "little better than could be obtained by the toss of a coin."[26] In 2005, the 11th Circuit Court of Appeals stated that "polygraphy did not enjoy general acceptance from the scientific community".[27] In 2001, William Iacono, Professor of Psychology and Neuroscience at the University of Minnesota, concluded: Although the CQT [Control Question Test] may be useful as an investigative aid and tool to induce confessions, it does not pass muster as a scientifically credible test. CQT theory is based on naive, implausible assumptions indicating (a) that it is biased against innocent individuals and (b) that it can be beaten simply by artificially augmenting responses to control questions. Although it is not possible to adequately assess the error rate of the CQT, both of these conclusions are supported by published research findings in the best social science journals (Honts et al., 1994; Horvath, 1977; Kleinmuntz & Szucko, 1984; Patrick & Iacono, 1991). Although defense attorneys often attempt to have the results of friendly CQTs admitted as evidence in court, there is no evidence supporting their validity and ample reason to doubt it. Members of scientific organizations who have the requisite background to evaluate the CQT are overwhelmingly skeptical of the claims made by polygraph proponents.[28] Polygraphs measure arousal, which can be affected by anxiety, anxiety disorders such as post-traumatic stress disorder (PTSD), nervousness, fear, confusion, hypoglycemia, psychosis, depression, substance-induced state (nicotine, stimulants), substance-withdrawal state (alcohol withdrawal) or other emotions; polygraphs do not measure "lies".[16][29][30] A polygraph cannot differentiate anxiety caused by dishonesty and anxiety caused by something else.[31] Since the polygraph does not measure lying, the Silent Talker Lie Detector inventors expected that adding a camera to film microexpressions would improve the accuracy of the evaluators. This did not happen in practice according to an article in the Intercept.[32] In 1983, the US Congress Office of Technology Assessment published a review of the technology[33] and found that there is at present only limited scientific evidence for establishing the validity of polygraph testing. Even where the evidence seems to indicate that polygraph testing detects deceptive subjects better than chance, significant error rates are possible, and examiner and examinee differences and the use of countermeasures may further affect validity.[34] In 2003, the National Academy of Sciences (NAS) issued a report entitled "The Polygraph and Lie Detection". The NAS found that "overall, the evidence is scanty and scientifically weak", concluding that 57 of the approximately 80 research studies that the American Polygraph Association relied on to reach their conclusions were significantly flawed.[35] These studies did show that specific-incident polygraph testing, in a person untrained in counter-measures, could discern the truth at "a level greater than chance, yet short of perfection". However, due to several flaws, the levels of accuracy shown in these studies "are almost certainly higher than actual polygraph accuracy of specific-incident testing in the field".[36] By adding a camera, the Silent Talker Lie Detector attempted to give more data to the evaluator by providing information about microexpressions. However adding the Silent Talker camera did not improve lie detection and was very expensive and cumbersome to include according to an article in the Intercept.[37] When polygraphs are used as a screening tool (in national security matters and for law enforcement agencies for example) the level of accuracy drops to such a level that "Its accuracy in distinguishing actual or potential security violators from innocent test takers is insufficient to justify reliance on its use in employee security screening in federal agencies."[6] The NAS concluded that the polygraph "may have some utility but that there is "little basis for the expectation that a polygraph test could have extremely high accuracy".[6] The NAS conclusions paralleled those of the earlier United States Congress Office of Technology Assessment report "Scientific Validity of Polygraph Testing: A Research Review and Evaluation".[38] Similarly, a report to Congress by the Moynihan Commission on Government Secrecy concluded that "The few Government-sponsored scientific research reports on polygraph validity (as opposed to its utility), especially those focusing on the screening of applicants for employment, indicate that the polygraph is neither scientifically valid nor especially effective beyond its ability to generate admissions".[39] Despite the NAS finding of a "high rate of false positives," failures to expose individuals such as Aldrich Ames and Larry Wu-Tai Chin, and other inabilities to show a scientific justification for the use of the polygraph, it continues to be employed.[37] Several proposed countermeasures designed to pass polygraph tests have been described. There are two major types of countermeasures: "general state" (intending to alter the physiological or psychological state of the subject during the test), and "specific point" (intending to alter the physiological or psychological state of the subject at specific periods during the examination, either to increase or decrease responses during critical examination periods).[29] General state: asked how he passed the polygraph test, Central Intelligence Agency officer turned KGB mole Aldrich Ames explained that he sought advice from his Soviet handler and received the simple instruction to: "Get a good night's sleep, and rest, and go into the test rested and relaxed. Be nice to the polygraph examiner, develop a rapport, and be cooperative and try to maintain your calm".[40] Additionally, Ames explained, "There's no special magic... Confidence is what does it. Confidence and a friendly relationship with the examiner... rapport, where you smile and you make him think that you like him".[41] Specific point: other suggestions for countermeasures include for the subject to mentally record the control and relevant questions as the examiner reviews them before the interrogation begins. During the interrogation the subject is supposed to carefully control their breathing while answering the relevant questions, and to try to artificially increase their heart rate during the control questions, for example by thinking of something scary or exciting, or by pricking themselves with a pointed object concealed somewhere on the body. In this way the results will not show a significant reaction to any of the relevant questions.[42] Law enforcement agencies and intelligence agencies in the United States are by far the biggest users of polygraph technology. In the United States alone most federal law enforcement agencies either employ their own polygraph examiners or use the services of examiners employed in other agencies.[43] In 1978 Richard Helms, the eighth Director of Central Intelligence, stated: We discovered there were some Eastern Europeans who could defeat the polygraph at any time. Americans are not very good at it, because we are raised to tell the truth and when we lie it is easy to tell we are lying. But we find a lot of Europeans and Asiatics can handle that polygraph without a blip, and you know they are lying and you have evidence that they are lying.[44] Susan McCarthy of Salon said in 2000 that "The polygraph is an American phenomenon, with limited use in a few countries, such as Canada, Israel and Japan."[45] In Armenia, government administered polygraphs are legal, at least for use in national security investigations. The National Security Service (NSS), Armenia's primary intelligence service, requires polygraph examinations of all new applicants.[46] Polygraph evidence became inadmissible in New South Wales courts under the Lie Detectors Act 1983. Under the same act, it is also illegal to use polygraphs for the purpose of granting employment, insurance, financial accommodation, and several other purposes for which polygraphs may be used in other jurisdictions.[47] In Canada, the 1987 decision of R v Béland, the Supreme Court of Canada rejected the use of polygraph results as evidence in court, finding that they were inadmissible. The polygraph is still used as a tool in the investigation of criminal acts and sometimes employed in the screening of employees for government organizations.[48] In the province of Ontario, the Employment Standards Act, 2000 prohibits employers from asking or requiring employees to undergo a polygraph test.[49][50] Police services are permitted to use polygraph tests as part of an investigation of the person consents.[51] In a majority of European jurisdictions, polygraphs are generally considered to be unreliable for gathering evidence, and are usually not used by local law enforcement agencies. Polygraph testing is widely seen in Europe to violate the right to remain silent.[52]: 62ff In England and Wales a polygraph test can be taken, but the results cannot be used in a court of law to prove a case.[53] However, the Offender Management Act 2007 put in place an option to use polygraph tests to monitor serious sex offenders on parole in England and Wales;[54] these tests became compulsory in 2014 for high risk sexual offenders currently on parole in England and Wales.[55] The Supreme Court of Poland declared on January 29, 2015, that the use of polygraph in interrogation of suspects is forbidden by the Polish Code of Criminal Procedure. Its use might be allowed though if the suspect has been already accused of a crime and if the interrogated person consents of the use of a polygraph. Even then, the use of polygraph can never be used as a substitute of actual evidence.[56] As of 2017, the justice ministry and Supreme Court of both of the Netherlands and Germany had rejected use of polygraphs.[52]: 62ff[57] According to the 2017 book Psychology and Law: Bridging the Gap by psychologists David Canter and Rita Žukauskiene Belgium was the European country with the most prevalent use of polygraph testing by police, with about 300 polygraphs carried out each year in the course of police investigations. The results are not considered viable evidence in bench trials, but have been used in jury trials.[52]: 62ff In Lithuania, "polygraphs have been in use since 1992",[58] with law enforcement utilizing the Event Knowledge Test (a "modification"[59] of the Concealed Information Test) in criminal investigations. In 2008, an Indian court adopted the Brain Electrical Oscillation Signature Profiling test as evidence to convict a woman who was accused of murdering her fiancé.[60] It was the first time that the result of polygraph was used as evidence in court.[61] On May 5, 2010, The Supreme Court of India declared use of narcoanalysis, brain mapping and polygraph tests on suspects as illegal and against the constitution if consent is not obtained and forced.[62] Article 20(3) of the Indian Constitution states: "No person accused of any offence shall be compelled to be a witness against himself."[63] Polygraph tests are still legal if the defendant requests one.[64] The Supreme Court of Israel, in Civil Appeal 551/89 (Menora Insurance v. Jacob Sdovnik), ruled that the polygraph has not been recognized as a reliable device. In other decisions, polygraph results were ruled inadmissible in criminal trials. Polygraph results are only admissible in civil trials if the person being tested agrees to it in advance.[65] The results of polygraph tests are inadmissible in court in the Philippines.[66][67] The National Bureau of Investigation, however, uses polygraphs in aid of investigation.[68] Brochure of the Defense Security Service (DSS) about polygraph testing Demonstrating the administration of the polygraph, the polygrapher making notes on the readouts. 1970s "The Truth About the Polygraph" (National Security Agency (NSA)-produced video on the polygraph process) In 2018, Wired magazine reported that an estimated 2.5 million polygraph tests were given each year in the United States, with the majority administered to paramedics, police officers, firefighters, and state troopers. The average cost to administer the test is more than $700 and is part of a $2 billion industry.[69] In 2007[update], polygraph testimony was admitted by stipulation in 19 states, and was subject to the discretion of the trial judge in federal court. The use of polygraph in court testimony remains controversial, although it is used extensively in post-conviction supervision, particularly of sex offenders. In Daubert v. Merrell Dow Pharmaceuticals, Inc. (1993),[70] the old Frye standard was lifted and all forensic evidence, including polygraph, had to meet the new Daubert standard in which "underlying reasoning or methodology is scientifically valid and properly can be applied to the facts at issue." While polygraph tests are commonly used in police investigations in the US, no defendant or witness can be forced to undergo the test unless they are under the supervision of the courts.[71] In United States v. Scheffer (1998),[72] the US Supreme Court left it up to individual jurisdictions whether polygraph results could be admitted as evidence in court cases. Nevertheless, it is used extensively by prosecutors, defense attorneys, and law enforcement agencies. In the states of Rhode Island, Massachusetts, Maryland, New Jersey, Oregon, Delaware and Iowa it is illegal for any employer to order a polygraph either as conditions to gain employment, or if an employee has been suspected of wrongdoing.[73][74] The Employee Polygraph Protection Act of 1988 (EPPA) generally prevents employers from using lie detector tests, either for pre-employment screening or during the course of employment, with certain exemptions.[75] As of 2013, about 70,000 job applicants are polygraphed by the federal government on an annual basis.[76] In the United States, the State of New Mexico admits polygraph testing in front of juries under certain circumstances.[77] In 2010 the NSA produced a video explaining its polygraph process.[78] The video, ten minutes long, is titled "The Truth About the Polygraph" and was posted to the website of the Defense Security Service. Jeff Stein of The Washington Post said that the video portrays "various applicants, or actors playing them—it's not clear—describing everything bad they had heard about the test, the implication being that none of it is true."[79] AntiPolygraph.org argues that the NSA-produced video omits some information about the polygraph process; it produced a video responding to the NSA video.[78] George Maschke, the founder of the website, accused the NSA polygraph video of being "Orwellian".[79] The polygraph was invented in 1921 by John Augustus Larson, a medical student at the University of California, Berkeley and a police officer of the Berkeley Police Department in Berkeley, California.[80] The polygraph was on the Encyclopædia Britannica 2003 list of greatest inventions, described as inventions that "have had profound effects on human life for better or worse."[81] In 2013, the US federal government had begun indicting individuals who stated that they were teaching methods on how to defeat a polygraph test.[76][82][83] During one of those investigations, upwards of 30 federal agencies were involved in investigations of almost 5000 people who had various degrees of contact with those being prosecuted or who had purchased books or DVDs on the topic of beating polygraph tests.[84][85][86] In 1995, Harold James Nicholson, a Central Intelligence Agency (CIA) employee later convicted of spying for Russia, had undergone his periodic five-year reinvestigation, in which he showed a strong probability of deception on questions regarding relationships with a foreign intelligence unit. This polygraph test later led to an investigation which resulted in his eventual arrest and conviction. In most cases, however, polygraphs are more of a tool to "scare straight" those who would consider espionage. Jonathan Pollard was advised by his Israeli handlers that he was to resign his job from American intelligence if he was ever told he was subject to a polygraph test.[citation needed] Likewise, John Anthony Walker was advised by his handlers not to engage in espionage until he had been promoted to the highest position for which a polygraph test was not required, to refuse promotion to higher positions for which polygraph tests were required, and to retire when promotion was mandated.[6] In 1983, CIA employee Edward Lee Howard was dismissed when, during a polygraph screening, he truthfully answered a series of questions admitting to minor crimes such as petty theft and drug abuse. In retaliation for his perceived unjust punishment for minor offenses, he later sold his knowledge of CIA operations to the Soviet Union.[87] Polygraph tests may not deter espionage. From 1945 to the present, at least six Americans have committed espionage while successfully passing polygraph tests. Notable cases of two men who created a false negative result with the polygraphs were Larry Wu-Tai Chin, who spied for China, and Aldrich Ames, who was given two polygraph examinations while with the CIA, the first in 1986 and the second in 1991, while spying for the Soviet Union/Russia. The CIA reported that he passed both examinations after experiencing initial indications of deception.[88] According to a Senate investigation, an FBI review of the first examination concluded that the indications of deception were never resolved.[89] Ana Belen Montes, a Cuban spy, passed a counterintelligence scope polygraph test administered by the US Defense Intelligence Agency (DIA) in 1994.[90] Despite these errors, in August 2008, the DIA announced that it would subject each of its 5,700 prospective and current employees to polygraph testing at least once annually.[91] This expansion of polygraph screening at DIA occurred while DIA polygraph managers ignored documented technical problems discovered in the Lafayette computerized polygraph system.[92] The DIA uses computerized Lafayette polygraph systems for routine counterintelligence testing. The impact of the technical flaws within the Lafayette system on the analysis of recorded physiology and on the final polygraph test evaluation is currently unknown.[93] In 2012, a McClatchy investigation found that the National Reconnaissance Office was possibly breaching ethical and legal boundaries by encouraging its polygraph examiners to extract personal and private information from US Department of Defense personnel during polygraph tests that purported to be limited in scope to counterintelligence matters.[94] Allegations of abusive polygraph practices were brought forward by former NRO polygraph examiners.[95] Most polygraph researchers have focused more on the exam's predictive value on a subject's guilt. However, there have been no empirical theories established to explain how a polygraph measures deception. A 2010 study indicated that functional magnetic resonance imaging (fMRI) may benefit in explaining the psychological correlations of polygraph exams. It could also explain which parts of the brain are active when subjects use artificial memories.[clarification needed][96] Most brain activity occurs in both sides of the prefrontal cortex, which is linked to response inhibition. This indicates that deception may involve inhibition of truthful responses.[97] Some researchers believe that reaction time (RT) based tests may replace polygraphs in concealed information detection. RT based tests differ from polygraphs in stimulus presentation duration and can be conducted without physiological recording as subject response time is measured via computer. However, researchers have found limitations to these tests as subjects voluntarily control their reaction time, deception can still occur within the response deadline, and the test itself lacks physiological recording.[98] Earlier societies utilized elaborate methods of lie detection which mainly involved torture. For instance, in the Middle Ages, boiling water was used to detect liars, as it was believed honest men would withstand it better than liars.[99] Early devices for lie detection include an 1895 invention of Cesare Lombroso used to measure changes in blood pressure for police cases, a 1904 device by Vittorio Benussi used to measure breathing, the Mackenzie-Lewis Polygraph first developed by James Mackenzie in 1906 and an abandoned project by American William Moulton Marston which used blood pressure to examine German prisoners of war (POWs).[100] Marston said he found a strong positive correlation between systolic blood pressure and lying.[16] Marston wrote a second paper on the concept in 1915, when finishing his undergraduate studies. He entered Harvard Law School and graduated in 1918, re-publishing his earlier work in 1917.[101] Marston's main inspiration for the device was his wife, Elizabeth Holloway Marston.[99] "According to Marston's son, it was his mother Elizabeth, Marston's wife, who suggested to him that 'When she got mad or excited, her blood pressure seemed to climb'" (Lamb, 2001). Although Elizabeth is not listed as Marston's collaborator in his early work, Lamb, Matte (1996), and others refer directly and indirectly to Elizabeth's work on her husband's deception research. She also appears in a picture taken in his polygraph laboratory in the 1920s (reproduced in Marston, 1938).[102] Despite his predecessors' contributions, Marston styled himself the "father of the polygraph". (Today he is often equally or more noted as the creator of the comic book character Wonder Woman and her Lasso of Truth, which can force people to tell the truth.)[103] Marston remained the device's primary advocate, lobbying for its use in the courts. In 1938 he published a book, The Lie Detector Test, wherein he documented the theory and use of the device.[104] In 1938 he appeared in advertising by the Gillette company claiming that the polygraph showed Gillette razors were better than the competition.[105][106][107] A device recording both blood pressure and breathing was invented in 1921 by John Augustus Larson of the University of California and first applied in law enforcement work by the Berkeley Police Department under its nationally renowned police chief August Vollmer.[108] Further work on this device was done by Leonarde Keeler.[109] As Larson's protege, Keeler updated the device by making it portable and added the galvanic skin response to it in 1939. His device was then purchased by the FBI, and served as the prototype of the modern polygraph.[99][108] Several devices similar to Keeler's polygraph version included the Berkeley Psychograph, a blood pressure-pulse-respiration recorder developed by C. D. Lee in 1936[110] and the Darrow Behavior Research Photopolygraph, which was developed and intended solely for behavior research experiments.[110][111][112] A device which recorded muscular activity accompanying changes in blood pressure was developed in 1945 by John E. Reid, who claimed that greater accuracy could be obtained by making these recordings simultaneously with standard blood pressure-pulse-respiration recordings.[110][113] Lie detection has a long history in mythology and fairy tales; the polygraph has allowed modern fiction to use a device more easily seen as scientific and plausible. Notable instances of polygraph usage include uses in crime and espionage themed television shows and some daytime television talk shows, cartoons and films. Numerous TV shows have been called Lie Detector or featured the device. The first Lie Detector TV show aired in the 1950s, created and hosted by Ralph Andrews. In the 1960s Andrews produced a series of specials hosted by Melvin Belli. In the 1970s the show was hosted by Jack Anderson. In early 1983 Columbia Pictures Television put on a syndicated series hosted by F. Lee Bailey.[114] In 1998 TV producer Mark Phillips with his Mark Phillips Philms & Telephision put Lie Detector back on the air on the FOX Network—on that program Ed Gelb with host Marcia Clark questioned Mark Fuhrman about the allegation that he "planted the bloody glove". In 2005 Phillips produced Lie Detector as a series for PAX/ION; some of the guests included Paula Jones, Reverend Paul Crouch accuser Lonny Ford, Ben Rowling, Jeff Gannon and Swift Boat Vet, Steve Garner.[115] In the UK, shows such as The Jeremy Kyle Show used polygraph tests extensively. The show was ultimately canceled when a participant committed suicide shortly after being polygraphed. The guest was slated by Kyle on the show for failing the polygraph, but no other evidence has come forward to prove any guilt. Producers later admitted in the inquiry that they were unsure on how accurate the tests performed were.[116] In the Fox game show The Moment of Truth, contestants are privately asked personal questions a few days before the show while hooked to a polygraph. On the show they asked the same questions in front of a studio audience and members of their family. In order to advance in the game they must give a "truthful" answer as determined by the previous polygraph exam.[117] Daytime talk shows, such as Maury Povich and Steve Wilkos, have used polygraphs to supposedly detect deception in interview subjects on their programs that pertain to cheating, child abuse, and theft.[118] In episode 93 of the US science show MythBusters, the hosts attempted to fool the polygraph by using pain when answering truthfully, in order to test the notion that polygraphs interpret truthful and non-truthful answers as the same. They also attempted to fool the polygraph by thinking pleasant thoughts when lying and thinking stressful thoughts when telling the truth, to try to confuse the machine. However, neither technique was successful for a number of reasons. Michael Martin correctly identified each guilty and innocent subject. Martin suggested that when conducted properly, polygraphs are correct 98% of the time, but no scientific evidence has been offered for this.[119] The history of the polygraph is the subject of the documentary film The Lie Detector, which first aired on American Experience on January 3, 2023.[120] A hand-held lie detector is being deployed by the US Department of Defense according to a report in 2008 by investigative reporter Bill Dedman of NBC News. The Preliminary Credibility Assessment Screening System, or PCASS, captures less physiological information than a polygraph, and uses an algorithm, not the judgment of a polygraph examiner, to render a decision whether it believes the person is being deceptive or not. The device was first used in Afghanistan by US Army troops. The Department of Defense ordered its use be limited to non-US persons, in overseas locations only.[121] Polygraphy has been faulted for failing to trap known spies such as double-agent Aldrich Ames, who passed two polygraph tests while spying for the Soviet Union.[91][122] Ames failed several tests while at the CIA that were never acted on.[123] Other spies who passed the polygraph include Karl Koecher,[124] Ana Montes,[125] and Leandro Aragoncillo.[126] CIA spy Harold James Nicholson failed his polygraph examinations, which aroused suspicions that led to his eventual arrest.[127] Polygraph examination and background checks failed to detect Nada Nadim Prouty, who was not a spy but was convicted for improperly obtaining US citizenship and using it to obtain a restricted position at the FBI.[128] The polygraph also failed to catch Gary Ridgway, the "Green River Killer". Another suspect allegedly failed a given lie detector test, whereas Ridgway passed.[16] Ridgway passed a polygraph in 1984; he confessed almost 20 years later when confronted with DNA evidence.[129] Conversely, innocent people have been known to fail polygraph tests. In Wichita, Kansas in 1986, Bill Wegerle was suspected of murdering his wife Vicki Wegerle because he failed two polygraph tests (one administered by the police, the other conducted by an expert that Wegerle had hired), although he was neither arrested nor convicted of her death. In March 2004, evidence surfaced connecting her death to the serial killer known as BTK, and in 2005 DNA evidence from the Wegerle murder confirmed that BTK was Dennis Rader, exonerating Wegerle.[130] Prolonged polygraph examinations are sometimes used as a tool by which confessions are extracted from a defendant, as in the case of Richard Miller, who was persuaded to confess largely by polygraph results combined with appeals from a religious leader.[131] In the Watts family murders, Christopher Watts failed one such polygraph test and subsequently confessed to murdering his wife.[132] In the 2002 disappearance of seven-year-old Danielle van Dam of San Diego, police suspected neighbor David Westerfield; he became the prime suspect when he allegedly failed a polygraph test.[133] United States portal Bogus pipeline Cleve Backster Doug Williams (polygraph critic) Ecological fallacy Ronald Pelton Voice stress analysis P300 (neuroscience)#Applications

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2Broadband cellular network standard For other uses, see 5G (disambiguation). 3GPP logo of 5G Part of a series on the fourth generation technology Analog 0G1G (1.5G) Digital 2G (2.5G, 2.75G, 2.9G)3G (3.5G, 3.75G, 3.9G)3.95G4G (4G/4.5G, 4.5G, 4.9G)5G (5.5G)6G Mobile telecommunications5G network An Android phone, showing that it is connected to a 5G network In telecommunications, 5G is the "fifth generation" of cellular network technology, as the successor to the fourth generation (4G), and has been deployed by mobile operators worldwide since 2019. Compared to 4G, 5G networks offer not only higher download speeds, with a peak speed of 10 gigabits per second (Gbit/s),[a] but also substantially lower latency, enabling near-instantaneous communication through cellular base stations and antennae.[1] There is one global unified 5G standard: 5G New Radio (5G NR),[2] which has been developed by the 3rd Generation Partnership Project (3GPP) based on specifications defined by the International Telecommunication Union (ITU) under the IMT-2020 requirements.[3] The increased bandwidth of 5G over 4G allows them to connect more devices simultaneously and improving the quality of cellular data services in crowded areas.[4] These features make 5G particularly suited for applications requiring real-time data exchange, such as extended reality (XR), autonomous vehicles, remote surgery, and industrial automation. Additionally, the increased bandwidth is expected to drive the adoption of 5G as a general Internet service provider (ISP), particularly through fixed wireless access (FWA), competing with existing technologies such as cable Internet, while also facilitating new applications in the machine-to-machine communication and the Internet of Things (IoT), the latter of which may include diverse applications such as smart cities, connected infrastructure, industrial IoT, and automated manufacturing processes. Unlike 4G, which was primarily designed for mobile broadband, 5G can handle millions of IoT devices with stringent performance requirements, such as real-time sensor data processing and edge computing. 5G networks also extend beyond terrestrial infrastructure, incorporating non-terrestrial networks (NTN) such as satellites and high-altitude platforms, to provide global coverage, including remote and underserved areas. 5G deployment faces challenges such as significant infrastructure investment, spectrum allocation, security risks, and concerns about energy efficiency and environment impact associated with the use of higher frequency bands. However, it is expected to drive advancements in sectors like healthcare, transportation, and entertainment. Mobile base station at Hatta city, UAE 5G networks are cellular networks,[5] in which the service area is divided into small geographical areas called cells. All 5G wireless devices in a cell communicate by radio waves with a cellular base station via fixed antennas, over frequencies assigned by the base station. The base stations, termed nodes, are connected to switching centers in the telephone network and routers for Internet access by high-bandwidth optical fiber or wireless backhaul connections. As in other cellular networks, a mobile device moving from one cell to another is automatically handed off seamlessly. The industry consortium setting standards for 5G, the 3rd Generation Partnership Project (3GPP), defines "5G" as any system using 5G NR (5G New Radio) software—a definition that came into general use by late 2018. 5G continues to use OFDM encoding. Several network operators use millimeter waves or mmWave called FR2 in 5G terminology, for additional capacity and higher throughputs. Millimeter waves have a shorter range than the lower frequency microwaves, therefore the cells are of a smaller size. Millimeter waves also have more trouble passing through building walls and humans. Millimeter-wave antennas are smaller than the large antennas used in previous cellular networks. The increased data rate is achieved partly by using additional higher-frequency radio waves in addition to the low- and medium-band frequencies used in previous cellular networks. For providing a wide range of services, 5G networks can operate in three frequency bands—low, medium or high. 5G can be implemented in low-band, mid-band or high-band millimeter-wave. Low-band 5G uses a similar frequency range to 4G smartphones, 600–900 MHz, which can potentially offer higher download speeds than 4G: 5–250 megabits per second (Mbit/s).[6][7] Low-band cell towers have a range and coverage area similar to 4G towers. Mid-band 5G uses microwaves of 1.7–4.7 GHz, allowing speeds of 100–900 Mbit/s, with each cell tower providing service up to several kilometers in radius. This level of service is the most widely deployed, and was deployed in many metropolitan areas in 2020. Some regions are not implementing the low band, making Mid-band the minimum service level. High-band 5G uses frequencies of 24–47 GHz, near the bottom of the millimeter wave band, although higher frequencies may be used in the future. It often achieves download speeds in the gigabit-per-second (Gbit/s) range, comparable to co-axial cable Internet service. However, millimeter waves (mmWave or mmW) have a more limited range, requiring many small cells.[8] They can be impeded or blocked by materials in walls or windows or pedestrians.[9][10] Due to their higher cost, plans are to deploy these cells only in dense urban environments and areas where crowds of people congregate such as sports stadiums and convention centers. The above speeds are those achieved in actual tests in 2020, and speeds are expected to increase during rollout.[6] The spectrum ranging from 24.25 to 29.5 GHz has been the most licensed and deployed 5G mmWave spectrum range in the world.[11] Rollout of 5G technology has led to debate over its security and relationship with Chinese vendors. It has also been the subject of health concerns and misinformation, including discredited conspiracy theories linking it to the COVID-19 pandemic. The ITU-R has defined three main application areas for the enhanced capabilities of 5G. They are Enhanced Mobile Broadband (eMBB), Ultra Reliable Low Latency Communications (URLLC), and Massive Machine Type Communications (mMTC).[12] Only eMBB is deployed in 2020; URLLC and mMTC are several years away in most locations.[13] Enhanced Mobile Broadband (eMBB) uses 5G as a progression from 4G LTE mobile broadband services, with faster connections, higher throughput, and more capacity. This will benefit areas of higher traffic such as stadiums, cities, and concert venues.[14] Ultra-Reliable Low-Latency Communications (URLLC) refers to using the network for mission-critical applications that require uninterrupted and robust data exchange. Short-packet data transmission is used to meet both reliability and latency requirements of the wireless communication networks. Massive Machine-Type Communications (mMTC) would be used to connect to a large number of devices. 5G technology will connect some of the 50 billion connected IoT devices.[15] Most will use the less expensive Wi-Fi. Drones, transmitting via 4G or 5G, will aid in disaster recovery efforts, providing real-time data for emergency responders.[15] Most cars will have a 4G or 5G cellular connection for many services. Autonomous cars do not require 5G, as they have to be able to operate where they do not have a network connection.[16] However, most autonomous vehicles also feature tele-operations for mission accomplishment, and these greatly benefit from 5G technology.[17][18] The 5G Automotive Association has been promoting the C-V2X communication technology that will first be deployed in 4G. It provides for communication between vehicles and infrastructures.[19] A real time digital twin of the real object such as a turbine engine, aircraft, wind turbines, offshore platform and pipelines. 5G networks helps in building it due to the latency and throughput to capture near real-time IoT data and support digital twins. Mission-critical push-to-talk (MCPTT) and mission-critical video and data are expected to be furthered in 5G.[20] Fixed wireless connections will offer an alternative to fixed-line broadband (ADSL, VDSL, fiber optic, and DOCSIS connections) in some locations. Utilizing 5G technology, fixed wireless access (FWA) can deliver high-speed internet to homes and businesses without the need for extensive physical infrastructure. This approach is particularly beneficial in rural or underserved areas where traditional broadband deployment is too expensive or logistically challenging. 5G FWA can outperform older fixed-line technologies such as ADSL and VDSL in terms of speed and latency, making it suitable for bandwidth-intensive applications like streaming, gaming, and remote work.[21][22][23] Sony has tested the possibility of using local 5G networks to replace the SDI cables currently used in broadcast camcorders.[24] The 5G Broadcast tests started around 2020 (Orkney, Bavaria, Austria, Central Bohemia) based on FeMBMS (Further evolved multimedia broadcast multicast service).[25] The aim is to serve unlimited number of mobile or fixed devices with video (TV) and audio (radio) streams without these consuming any data flow or even being authenticated in a network. Main article: Voice over NR 5G networks, like 4G networks, do not natively support voice calls traditionally carried over circuit-switched technology. Instead, voice communication is transmitted over the IP network, similar to IPTV services. To address this, Voice over NR (VoNR) is implemented, allowing voice calls to be carried over the 5G network using the same packet-switched infrastructure as other IP-based services, such as video streaming and messaging. Similarly to how Voice over LTE (VoLTE) enables voice calls on 4G networks, VoNR (Vo5G) serves as the 5G equivalent for voice communication, but it requires a 5G standalone (SA) network to function.[26] This article possibly contains unsourced predictions, speculative material, or accounts of events that might not occur. Information must be verifiable and based on reliable published sources. Please help improve it by removing unsourced speculative content. (January 2022) (Learn how and when to remove this message) 5G is capable of delivering significantly faster data rates than 4G (5G is approximately 10 times faster than 4G),[27][28] with peak data rates of up to 20 gigabits per second (Gbps).[29] Furthermore, average 5G download speeds have been recorded at 186.3 Mbit/s in the U.S. by T-Mobile,[30] while South Korea, as of May 2022[update], leads globally with average speeds of 432 megabits per second (Mbps).[31][32] 5G networks are also designed to provide significantly more capacity than 4G networks, with a projected 100-fold increase in network capacity and efficiency.[33] The most widely used form of 5G, sub-6 GHz (mid-band), is capable of delivering data rates ranging from 10 to 1,000 megabits per second (Mbps), with a much greater reach than mm Wave bands. C-Band (n77/n78) was deployed by various U.S. operators in 2022 in the sub-6 bands, although its deployment by Verizon and AT&T was delayed until early January 2022 due to safety concerns raised by the Federal Aviation Administration. The record for 5G speed in a deployed network is 5.9 Gbit/s as of 2023, but this was tested before the network was launched.[34] Low-band frequencies (such as n5) offer a greater coverage area for a given cell, but their data rates are lower than those of mid and high bands in the range of 5–250 megabits per second (Mbps).[7] In 5G, the ideal "air latency" is of the order of 8 to 12 milliseconds i.e., excluding delays due to HARQ retransmissions, handovers, etc. Retransmission latency and backhaul latency to the server must be added to the "air latency" for correct comparisons. Verizon reported the latency on its 5G early deployment is 30 ms.[35] Edge Servers close to the towers have the possibility to reduce round-trip time (RTT) latency to 14 milliseconds and the minimum jitter to 1.84 milliseconds.[36] Latency is much higher during handovers; ranging from 50 to 500 milliseconds depending on the type of handover[citation needed]. Reducing handover interruption time is an ongoing area of research and development; options include modifying the handover margin (offset) and the time-to-trigger (TTT). 5G uses an adaptive modulation and coding scheme (MCS) to keep the block error rate (BLER) extremely low. Whenever the error rate crosses a (very low) threshold the transmitter will switch to a lower MCS, which will be less error-prone. This way speed is sacrificed to ensure an almost zero error rate. The range of 5G depends on many factors: transmit power, frequency, and interference. For example, mmWave (e.g.: band n258) will have a lower range than mid-band (e.g.: band n78) which will have a lower range than low-band (e.g.: band n5) Given the marketing hype on what 5G can offer, simulators and drive tests are used by cellular service providers for the precise measurement of 5G performance. Initially, the term was associated with the International Telecommunication Union's IMT-2020 standard, which required a theoretical peak download speed of 20 gigabits per second and 10 gigabits per second upload speed, along with other requirements.[29] Then, the industry standards group 3GPP chose the 5G NR (New Radio) standard together with LTE as their proposal for submission to the IMT-2020 standard.[37][38] 5G NR can include lower frequencies (FR1), below 6 GHz, and higher frequencies (FR2), above 24 GHz.[39] However, the speed and latency in early FR1 deployments, using 5G NR software on 4G hardware (non-standalone), are only slightly better than new 4G systems, estimated at 15 to 50% better.[40][41] The standard documents are organized by 3rd Generation Partnership Project (3GPP),[42][43] with its system architecture defined in TS 23.501.[44] The packet protocol for mobility management (establishing connection and moving between base stations) and session management (connecting to networks and network slices) is described in TS 24.501.[45] Specifications of key data structures are found in TS 23.003.[46] DECT NR+ is a related, non-cellular standard of 5G based on DECT-2020 specifications based on a mesh network.[47][48] Further information: Fronthaul and Common Public Radio Interface IEEE covers several areas of 5G with a core focus on wireline sections between the Remote Radio Head (RRH) and Base Band Unit (BBU). The 1914.1 standards focus on network architecture and dividing the connection between the RRU and BBU into two key sections. Radio Unit (RU) to the Distributor Unit (DU) being the NGFI-I (Next Generation Fronthaul Interface) and the DU to the Central Unit (CU) being the NGFI-II interface allowing a more diverse and cost-effective network. NGFI-I and NGFI-II have defined performance values which should be compiled to ensure different traffic types defined by the ITU are capable of being carried.[page needed] The IEEE 1914.3 standard is creating a new Ethernet frame format capable of carrying IQ data in a much more efficient way depending on the functional split utilized. This is based on the 3GPP definition of functional splits.[page needed] Main article: 5G NR 5G NR (5G New Radio) is the de facto air interface developed for 5G networks.[49] It is the global standard for 3GPP 5G networks.[50] The study of 5G NR within 3GPP started in 2015, and the first specification was made available by the end of 2017. While the 3GPP standardization process was ongoing, the industry had already begun efforts to implement infrastructure compliant with the draft standard, with the first large-scale commercial launch of 5G NR having occurred at the end of 2018. Since 2019, many operators have deployed 5G NR networks and handset manufacturers have developed 5G NR enabled handsets.[51] 5Gi is an alternative 5G variant developed in India. It was developed in a joint collaboration between IIT Madras, IIT Hyderabad, TSDSI, and the Centre of Excellence in Wireless Technology (CEWiT).[citation needed] 5Gi uses Low Mobility Large Cell (LMLC) to extend 5G connectivity and the range of a base station.[52] In April 2022, 5Gi was merged with the global 5G NR standard in the 3GPP Release 17 specifications.[53] 5G TF: American carrier Verizon used a pre-standard variation of 5G known as 5G TF (Verizon 5G Technical Forum) for Fixed Wireless Access in 2018. The 5G service provided to customers in this standard is incompatible with 5G NR. Verizon has since migrated to 5G NR.[54] 5G-SIG: KT Corporation had a pre-standard variation of 5G developed called 5G-SIG. This was deployed at the Pyeongchang 2018 Winter Olympics.[55] In the Internet of things (IoT), 3GPP is going to submit the evolution of NB-IoT and eMTC (LTE-M) as 5G technologies for the LPWA (Low Power Wide Area) use case.[56] Standards are being developed by 3GPP to provide access to end devices via non-terrestrial networks (NTN), i.e. satellite or airborne telecommunication equipment to allow for better coverage outside of populated or otherwise hard to reach locations.[57][58] The enhanced communication quality relies on the unique properties of Air to Ground channel. Several manufacturers have announced and released hardware that integrates 5G with satellite networks: Samsung Electronics introduced a standardized 5G NTN modem technology in Korea in February 2023,[59] which is integrated into their Exynos Modem 5300, facilitating smartphone-satellite communication. MediaTek launched the world's first commercially available 5G IoT-NTN chipset, MT6825, capable of automatic satellite message receipt and extensive power efficiency.[60][61] Qualcomm, in collaboration with Skylo, announced new satellite IoT solutions on June 22, 2023, including the Qualcomm 212S and 9205S modems, supporting the Qualcomm Aware platform for real-time asset tracking and device management.[62] Motorola's Defy Satellite Link hotspot, powered by MediaTek's MT6825, became available in June 2023, providing a portable satellite messaging solution with robust battery life and built-in GPS.[63][64] Rakuten Symphony, in collaboration with Supermicro, announced high-performing Open RAN technologies and storage systems for operators of cloud-based mobile services.[65] 5G-Advanced (also known as 5.5G or 5G-A) is an evolutionary upgrade to 5G technology, defined under the 3GPP Release 18 standard. It serves as a transitional phase between 5G and future 6G networks, focusing on performance optimization, enhanced spectral efficiency, energy efficiency, and expanded functionality. While 5G introduced advanced applications such as enhanced mobile broadband (eMBB), ultra-reliable low-latency communication (URLLC), and massive machine-type communication (mMTC), 5G-Advanced builds upon these capabilities to support more advanced use cases and improve overall network efficiency.[66][67] 5G-Advanced would offer a theoretical 10 Gbps downlink, 1 Gbps uplink, 100 billion device connections and lower latency.[69] Additionally, 5G-Advanced integrates artificial intelligence (AI) and machine learning (ML) to optimize network operations, enabling smarter resource allocation and predictive maintenance. It also enhances network slicing, allowing highly customized virtual networks for specific use cases such as industrial automation, smart cities, and critical communication systems. 5G-Advanced aims to minimize service interruption times during handovers to nearly zero, ensuring robust connectivity for devices in motion, such as high-speed trains and autonomous vehicles. To further support emerging IoT applications, 5G-Advanced expands the capabilities of RedCap (Reduced Capability) devices, enabling their efficient use in scenarios that require low complexity and power consumption.[70][71] Furthermore, 5G-Advanced introduces advanced time synchronization methods independent of GNSS, providing more precise timing for critical applications. For the first time in the development of mobile network standards defined by 3GPP, it offers fully independent geolocation capabilities, allowing position determination without relying on satellite systems such as GPS. The standard includes extended support for non-terrestrial networks (NTN), enabling communication via satellites and unmanned aerial vehicles, which facilitates connectivity in remote or hard-to-reach areas.[72] In December 2023, Finnish operator DNA demonstrated 10 Gbps speeds on its network using 5G-Advanced technology.[73][74] The Release 18 specifications were finalized by mid-2024.[75][76] On February 27, 2025, Elisa announced in Finland the deployment of the first 5G-Advanced network in Finland.[77] In March 2025, China Mobile started deployment of 5G-Advanced network in Hangzhou.[78] See also: List of 5G NR networks 5G 3.5 GHz cell site of Deutsche Telekom in Darmstadt, Germany 5G 3.5 GHz cell site of Vodafone in Karlsruhe, Germany Beyond mobile operator networks, 5G is also expected to be used for private networks with applications in industrial IoT, enterprise networking, and critical communications, in what being described as NR-U (5G NR in Unlicensed Spectrum)[79] and Non-Public Networks (NPNs) operating in licensed spectrum. By the mid-to-late 2020s, standalone private 5G networks are expected to become the predominant wireless communications medium to support the ongoing Industry 4.0 revolution for the digitization and automation of manufacturing and process industries.[80] 5G was expected to increase phone sales.[81] Initial 5G NR launches depended on pairing with existing LTE (4G) infrastructure in non-standalone (NSA) mode (5G NR radio with 4G core), before maturation of the standalone (SA) mode with the 5G core network.[82] As of April 2019, the Global Mobile Suppliers Association had identified 224 operators in 88 countries that have demonstrated, are testing or trialing, or have been licensed to conduct field trials of 5G technologies, are deploying 5G networks or have announced service launches.[83] The equivalent numbers in November 2018 were 192 operators in 81 countries.[84] The first country to adopt 5G on a large scale was South Korea, in April 2019. Swedish telecoms giant Ericsson predicted that 5G Internet will cover up to 65% of the world's population by the end of 2025.[85] Also, it plans to invest 1 billion reals ($238.30 million) in Brazil to add a new assembly line dedicated to fifth-generation technology (5G) for its Latin American operations.[86] When South Korea launched its 5G network, all carriers used Samsung, Ericsson, and Nokia base stations and equipment, except for LG U Plus, who also used Huawei equipment.[87][88] Samsung was the largest supplier for 5G base stations in South Korea at launch, having shipped 53,000 base stations at the time, out of 86,000 base stations installed across the country at the time.[89] The first fairly substantial deployments were in April 2019. In South Korea, SK Telecom claimed 38,000 base stations, KT Corporation 30,000 and LG U Plus 18,000; of which 85% are in six major cities.[90] They are using 3.5 GHz (sub-6) spectrum in non-standalone (NSA) mode and tested speeds were from 193 to 430 Mbit/s down.[91] 260,000 signed up in the first month and 4.7 million by the end of 2019.[92] T-Mobile US was the first company in the world to launch a commercially available 5G NR Standalone network.[93] Nine companies sell 5G radio hardware and 5G systems for carriers: Altiostar, Cisco Systems, Datang Telecom/Fiberhome, Ericsson, Huawei, Nokia, Qualcomm, Samsung, and ZTE.[94][95][96][97][98][99][100] As of 2023, Huawei is the leading 5G equipment manufacturer and has the greatest market share of 5G equipment and has built approximately 70% of worldwide 5G base stations.[101]:182 Large quantities of new radio spectrum (5G NR frequency bands) have been allocated to 5G.[102] For example, in July 2016, the U.S. Federal Communications Commission (FCC) freed up vast amounts of bandwidth in underused high-band spectrum for 5G. The Spectrum Frontiers Proposal (SFP) doubled the amount of millimeter-wave unlicensed spectrum to 14 GHz and created four times the amount of flexible, mobile-use spectrum the FCC had licensed to date.[103] In March 2018, European Union lawmakers agreed to open up the 3.6 and 26 GHz bands by 2020.[104] As of March 2019[update], there are reportedly 52 countries, territories, special administrative regions, disputed territories and dependencies that are formally considering introducing certain spectrum bands for terrestrial 5G services, are holding consultations regarding suitable spectrum allocations for 5G, have reserved spectrum for 5G, have announced plans to auction frequencies or have already allocated spectrum for 5G use.[105] 5G connectivity on a Samsung Galaxy S10 In March 2019, the Global Mobile Suppliers Association released the industry's first database tracking worldwide 5G device launches.[106] In it, the GSA identified 23 vendors who have confirmed the availability of forthcoming 5G devices with 33 different devices including regional variants. There were seven announced 5G device form factors: (telephones (×12 devices), hotspots (×4), indoor and outdoor customer-premises equipment (×8), modules (×5), Snap-on dongles and adapters (×2), and USB terminals (×1)).[107] By October 2019, the number of announced 5G devices had risen to 129, across 15 form factors, from 56 vendors.[108] In the 5G IoT chipset arena, as of April 2019 there were four commercial 5G modem chipsets (Intel, MediaTek, Qualcomm, Samsung) and one commercial processor/platform, with more launches expected in the near future.[109]Apr Apple iPhone showing that it is connected to a 5G Network On March 4, 2019, the first-ever all-5G smartphone Samsung Galaxy S10 5G was released. According to Business Insider, the 5G feature was showcased as more expensive in comparison with the 4G Samsung Galaxy S10e.[110] On March 19, 2020, HMD Global, the current maker of Nokia-branded phones, announced the Nokia 8.3 5G, which it claimed as having a wider range of 5G compatibility than any other phone released to that time. The mid-range model is claimed to support all 5G bands from 600 MHz to 3.8 GHz.[111] Google Pixel smartphones support 5G starting with the 4a 5G and Pixel 5,[112] while Apple smartphones support 5G starting with the iPhone 12.[113][114] See also: 5G NR frequency bands The air interface defined by 3GPP for 5G is known as 5G New Radio (5G NR), and the specification is subdivided into two frequency bands, FR1 (below 6 GHz) and FR2 (24–54 GHz) Otherwise known as sub-6, the maximum channel bandwidth defined for FR1 is 100 MHz, due to the scarcity of continuous spectrum in this crowded frequency range. The band most widely being used for 5G in this range is 3.3–4.2 GHz. The Korean carriers use the n78 band at 3.5 GHz. Some parties used the term "mid-band" frequency to refer to higher part of this frequency range that was not used in previous generations of mobile communication. The minimum channel bandwidth defined for FR2 is 50 MHz and the maximum is 400 MHz, with two-channel aggregation supported in 3GPP Release 15. Signals in this frequency range with wavelengths between 4 and 12 mm are called millimeter waves. The higher the carrier frequency, the greater the ability to support high data-transfer speeds. This is because a given channel bandwidth takes up a lower fraction of the carrier frequency, so high-bandwidth channels are easier to realize at higher carrier frequencies. 5G in the 24 GHz range or above use higher frequencies than 4G, and as a result, some 5G signals are not capable of traveling large distances (over a few hundred meters), unlike 4G or lower frequency 5G signals (sub 6 GHz). This requires placing 5G base stations every few hundred meters in order to use higher frequency bands. Also, these higher frequency 5G signals cannot penetrate solid objects easily, such as cars, trees, walls and even humans, because of the nature of these higher frequency electromagnetic waves. 5G cells can be deliberately designed to be as inconspicuous as possible, which finds applications in places like restaurants and shopping malls.[115] Cell types Deployment environment Max. number of users Output power (W) Max. distance from base station 5G NR FR2 Femtocell Homes, businesses Home: 4–8Businesses: 16–32 indoors: 0.01–0.1outdoors: 0.2–1 tens of meters Pico cell Public areas like shopping malls,airports, train stations, skyscrapers 64 to 128 indoors: 0.1–0.25outdoors: 1–5 tens of meters Micro cell Urban areas to fill coverage gaps 128 to 256 outdoors: 5−10 few hundreds of meters Metro cell Urban areas to provide additional capacity more than 250 outdoors: 10−20 hundreds of meters Wi-Fi(for comparison) Homes, businesses fewer than 50 indoors: 0.02–0.1outdoors: 0.2–1 few tens of meters See also: Multi-user MIMO MIMO (multiple-input and multiple-output) systems use multiple antennas at the transmitter and receiver ends of a wireless communication system. Multiple antennas use the spatial dimension for multiplexing in addition to the time and frequency ones, without changing the bandwidth requirements of the system. Spatial multiplexing gains allow for an increase in the number of transmission layers, thereby boosting system capacity. Massive MIMO antennas increases sector throughput and capacity density using large numbers of antennas. This includes Single User MIMO and Multi-user MIMO (MU-MIMO). Each antenna is individually-controlled and may embed radio transceiver components. Edge computing is delivered by computing servers closer to the ultimate user. It reduces latency, data traffic congestion[117][118] and can improve service availability.[119] Main article: Small cell Small cells are low-powered cellular radio access nodes that operate in licensed and unlicensed spectrum that have a range of 10 meters to a few kilometers. Small cells are critical to 5G networks, as 5G's radio waves can't travel long distances, because of 5G's higher frequencies.[120][121][122][123] Main article: Beamforming There are two kinds of beamforming (BF): digital and analog. Digital beamforming involves sending the data across multiple streams (layers), while analog beamforming shaping the radio waves to point in a specific direction. The analog BF technique combines the power from elements of the antenna array in such a way that signals at particular angles experience constructive interference, while other signals pointing to other angles experience destructive interference. This improves signal quality in the specific direction, as well as data transfer speeds. 5G uses both digital and analog beamforming to improve the system capacity.[124][125] One expected benefit of the transition to 5G is the convergence of multiple networking functions to achieve cost, power, and complexity reductions. LTE has targeted convergence with Wi-Fi band/technology via various efforts, such as License Assisted Access (LAA; 5G signal in unlicensed frequency bands that are also used by Wi-Fi) and LTE-WLAN Aggregation (LWA; convergence with Wi-Fi Radio), but the differing capabilities of cellular and Wi-Fi have limited the scope of convergence. However, significant improvement in cellular performance specifications in 5G, combined with migration from Distributed Radio Access Network (D-RAN) to Cloud- or Centralized-RAN (C-RAN) and rollout of cellular small cells can potentially narrow the gap between Wi-Fi and cellular networks in dense and indoor deployments. Radio convergence could result in sharing ranging from the aggregation of cellular and Wi-Fi channels to the use of a single silicon device for multiple radio access technologies.[126] NOMA (non-orthogonal multiple access) is a proposed multiple-access technique for future cellular systems via allocation of power.[127] Main articles: Software-defined networking, SD-WAN, Network function virtualization, and 5G network slicing Initially, cellular mobile communications technologies were designed in the context of providing voice services and Internet access. Today a new era of innovative tools and technologies is inclined towards developing a new pool of applications. This pool of applications consists of different domains such as the Internet of Things (IoT), web of connected autonomous vehicles, remotely controlled robots, and heterogeneous sensors connected to serve versatile applications.[128] In this context, network slicing has emerged as a key technology to efficiently embrace this new market model.[129] The 5G Service-Based architecture replaces the referenced-based architecture of the Evolved Packet Core that is used in 4G. The SBA breaks up the core functionality of the network into interconnected network functions (NFs), which are typically implemented as Cloud-Native Network Functions. These NFs register with the Network Repository Function (NRF) which maintains their state, and communicate with each other using the Service Communication Proxy (SCP). The interfaces between the elements all utilize RESTful APIs.[130] By breaking functionality down this way, mobile operators are able to utilize different infrastructure vendors for different functions, and the flexibility to scale each function independently as needed.[130] 5G Network Functions [131] NF Name NF Acronym Analogous EPC element Authentication Server Function AUSF MME / HSS (Authentication) Access and Mobility Management Function AMF MME Unstructured Data Storage Function UDSF N/A Network Exposure Function NEF N/A Network Repository Function NRF N/A Network Slice Specific Authentication and Authorization Function NSSAAF N/A Network Slice Selection Function NSSF N/A Policy Control Function PCF PCRF Session Management Function SMF MME / PGW-C Unified Data Management UDM HSS (DB Front End) Unified Data Repository UDR HSS (User Database) User Plane Function UPF SGW-U / PGW-U 5G radio Capability Management Function UCMF N/A Application Function AF AF (IMS) Network Data Analytics Function NWDAF N/A CHarging Function CHF CSCF In addition, the standard describes network entities for roaming and inter-network forwarding: the Security Edge Protection Proxy (SEPP), the Non-3GPP InterWorking Function (N3IWF), the Trusted Non-3GPP Gateway Function (TNGF), the Wireline Access Gateway Function (W-AGF), and the Trusted WLAN Interworking Function (TWIF). These can be deployed by operators as needed depending on their deployment. The channel coding techniques for 5G NR have changed from Turbo codes in 4G to polar codes for the control channels and LDPC (low-density parity check codes) for the data channels.[132][133] In December 2018, 3GPP began working on unlicensed spectrum specifications known as 5G NR-U, targeting 3GPP Release 16.[134] Qualcomm has made a similar proposal for LTE in unlicensed spectrum. 5G wireless power is a technology based on 5G standards that transfers wireless power.[135][136] It adheres to technical standards set by the 3rd Generation Partnership Project, the International Telecommunication Union, and the Institute of Electrical and Electronics Engineers. It utilizes extremely high frequency radio waves with wavelengths from one to ten millimeters, also known as mmWaves.[137][138] Up to 6μW of power has been captured from 5G signals at a distance of 180m by researchers at Georgia Tech.[135] Internet of things devices could benefit from 5G wireless power technology, given their low power requirements that are within the range of what has been achieved using 5G power capture.[139] See also: Concerns over Chinese involvement in 5G wireless networks and Criticism of Huawei § Espionage and security concerns A report published by the European Commission and European Agency for Cybersecurity details the security issues surrounding 5G. The report warns against using a single supplier for a carrier's 5G infrastructure, especially those based outside the European Union; Nokia and Ericsson are the only European manufacturers of 5G equipment.[140] On October 18, 2018, a team of researchers from ETH Zurich, the University of Lorraine and the University of Dundee released a paper entitled, "A Formal Analysis of 5G Authentication".[141][142] It alerted that 5G technology could open ground for a new era of security threats. The paper described the technology as "immature and insufficiently tested," and one that "enables the movement and access of vastly higher quantities of data, and thus broadens attack surfaces". Simultaneously, network security companies such as Fortinet,[143] Arbor Networks,[144] A10 Networks,[145] and Voxility[146] advised on personalized and mixed security deployments against massive DDoS attacks foreseen after 5G deployment. IoT Analytics estimated an increase in the number of IoT devices, enabled by 5G technology, from 7 billion in 2018 to 21.5 billion by 2025.[147] This can raise the attack surface for these devices to a substantial scale, and the capacity for DDoS attacks, cryptojacking, and other cyberattacks could boost proportionally.[142] In addition, the EPS solution for 5G networks has identified a design vulnerability. The vulnerability affects the operation of the device during cellular network switching.[148] Due to fears of potential espionage of users of Chinese equipment vendors, several countries (including the United States, Australia and the United Kingdom as of early 2019)[149] have taken actions to restrict or eliminate the use of Chinese equipment in their respective 5G networks. A 2012 U.S. House Permanent Select Committee on Intelligence report concluded that using equipment made by Huawei and ZTE, another Chinese telecommunications company, could "undermine core U.S. national security interests".[150] In 2018, six U.S. intelligence chiefs, including the directors of the CIA and FBI, cautioned Americans against using Huawei products, warning that the company could conduct "undetected espionage".[151] Further, a 2017 investigation by the FBI determined that Chinese-made Huawei equipment could disrupt U.S. nuclear arsenal communications.[152] Chinese vendors and the Chinese government have denied claims of espionage, but experts have pointed out that Huawei would have no choice but to hand over network data to the Chinese government if Beijing asked for it because of Chinese National Security Law.[153] In August 2020, the U.S. State Department launched "The Clean Network" as a U.S. government-led, bi-partisan effort to address what it described as "the long-term threat to data privacy, security, human rights and principled collaboration posed to the free world from authoritarian malign actors". Promoters of the initiative have stated that it has resulted in an "alliance of democracies and companies", "based on democratic values". On October 7, 2020, the UK Parliament's Defence Committee released a report claiming that there was clear evidence of collusion between Huawei and Chinese state and the Chinese Communist Party. The UK Parliament's Defence Committee said that the government should consider removal of all Huawei equipment from its 5G networks earlier than planned.[154] In December 2020, the United States announced that more than 60 nations, representing more than two thirds of the world's gross domestic product, and 200 telecom companies, had publicly committed to the principles of The Clean Network. This alliance of democracies included 27 of the 30 NATO members; 26 of the 27 EU members, 31 of the 37 OECD nations, 11 of the 12 Three Seas nations as well as Japan, Israel, Australia, Singapore, Taiwan, Canada, Vietnam, and India. The examples and perspective in this article deal primarily with the United States and do not represent a worldwide view of the subject. You may improve this article, discuss the issue on the talk page, or create a new article, as appropriate. (January 2022) (Learn how and when to remove this message) This section needs to be updated. Please help update this article to reflect recent events or newly available information. (January 2022) The spectrum used by various 5G proposals, especially the n258 band centered at 26 GHz, will be near that of passive remote sensing such as by weather and Earth observation satellites, particularly for water vapor monitoring at 23.8 GHz.[155] Interference is expected to occur due to such proximity and its effect could be significant without effective controls. An increase in interference already occurred with some other prior proximate band usages.[156][157] Interference to satellite operations impairs numerical weather prediction performance with substantially deleterious economic and public safety impacts in areas such as commercial aviation.[158][159] The concerns prompted U.S. Secretary of Commerce Wilbur Ross and NASA Administrator Jim Bridenstine in February 2019 to urge the FCC to delay some spectrum auction proposals, which was rejected.[160] The chairs of the House Appropriations Committee and House Science Committee wrote separate letters to FCC chairman Ajit Pai asking for further review and consultation with NOAA, NASA, and DoD, and warning of harmful impacts to national security.[161] Acting NOAA director Neil Jacobs testified before the House Committee in May 2019 that 5G out-of-band emissions could produce a 30% reduction in weather forecast accuracy and that the resulting degradation in ECMWF model performance would have resulted in failure to predict the track and thus the impact of Superstorm Sandy in 2012. The United States Navy in March 2019 wrote a memorandum warning of deterioration and made technical suggestions to control band bleed-over limits, for testing and fielding, and for coordination of the wireless industry and regulators with weather forecasting organizations.[162] At the 2019 quadrennial World Radiocommunication Conference (WRC), atmospheric scientists advocated for a strong buffer of −55 dBW, European regulators agreed on a recommendation of −42 dBW, and US regulators (the FCC) recommended a restriction of −20 dBW, which would permit signals 150 times stronger than the European proposal. The ITU decided on an intermediate −33 dBW until September 1, 2027, and after that a standard of −39 dBW.[163] This is closer to the European recommendation but even the delayed higher standard is much weaker than that pleaded for by atmospheric scientists, triggering warnings from the World Meteorological Organization (WMO) that the ITU standard, at 10 times less stringent than its recommendation, brings the "potential to significantly degrade the accuracy of data collected".[164] A representative of the American Meteorological Society (AMS) also warned of interference,[165] and the European Centre for Medium-Range Weather Forecasts (ECMWF), sternly warned, saying that society risks "history repeat[ing] itself" by ignoring atmospheric scientists' warnings (referencing global warming, monitoring of which could be imperiled).[166] In December 2019, a bipartisan request was sent from the US House Science Committee to the Government Accountability Office (GAO) to investigate why there is such a discrepancy between recommendations of US civilian and military science agencies and the regulator, the FCC.[167] The United States FAA has warned that radar altimeters on aircraft, which operate between 4.2 and 4.4 GHz, might be affected by 5G operations between 3.7 and 3.98 GHz. This is particularly an issue with older altimeters using RF filters[168] which lack protection from neighboring bands.[169] This is not as much of an issue in Europe, where 5G uses lower frequencies between 3.4 and 3.8 GHz.[170] Nonetheless, the DGAC in France has also expressed similar worries and recommended 5G phones be turned off or be put in airplane mode during flights.[171] On December 31, 2021, U.S. Transportation Secretary Pete Buttigieg and Steve Dickinson, administrator of the Federal Aviation Administration asked the chief executives of AT&T and Verizon to delay 5G implementation over aviation concerns. The government officials asked for a two-week delay starting on January 5, 2022, while investigations are conducted on the effects on radar altimeters. The government transportation officials also asked the cellular providers to hold off their new 5G service near 50 priority airports, to minimize disruption to air traffic that would be caused by some planes being disallowed from landing in poor visibility.[172] After coming to an agreement with government officials the day before,[173] Verizon and AT&T activated their 5G networks on January 19, 2022, except for certain towers near 50 airports.[174] AT&T scaled back its deployment even further than its agreement with the FAA required.[175] The FAA rushed to test and certify radar altimeters for interference so that planes could be allowed to perform instrument landings (e.g. at night and in low visibility) at affected airports. By January 16, it had certified equipment on 45% of the U.S. fleet, and 78% by January 20.[176] Airlines complained about the avoidable impact on their operations, and commentators said the affair called into question the competence of the FAA.[177] Several international airlines substituted different planes so they could avoid problems landing at scheduled airports, and about 2% of flights (320) were cancelled by the evening of January 19.[178] Further information: C band (IEEE) A number of 5G networks deployed on the radio frequency band of 3.3–3.6 GHz are expected to cause interference with C-Band satellite stations, which operate by receiving satellite signals at 3.4–4.2 GHz frequency.[179] This interference can be mitigated with low-noise block downconverters and waveguide filters.[179] In regions like the US and EU, the 6 GHz band is to be opened up for unlicensed applications, which would permit the deployment of 5G-NR Unlicensed, 5G version of LTE in unlicensed spectrum, as well as Wi-Fi 6e. However, interference could occur with the co-existence of different standards in the frequency band.[180] There have been concerns surrounding the promotion of 5G, questioning whether the technology is overhyped. There are questions on whether 5G will truly change the customer experience,[181] ability for 5G's mmWave signal to provide significant coverage,[182][183] overstating what 5G can achieve or misattributing continuous technological improvement to "5G",[184] lack of new use case for carriers to profit from,[185] wrong focus on emphasizing direct benefits on individual consumers instead of for internet of things devices or solving the last mile problem,[186] and overshadowing the possibility that in some aspects there might be other more appropriate technologies.[187] Such sort of concerns have also led to consumers not trusting information provided by cellular providers on the topic.[188] Main article: 5G misinformation Further information: Wireless device radiation and health There is a long history of fear and anxiety surrounding wireless signals that predates 5G technology. The fears about 5G are similar to those that have persisted throughout the 1990s and 2000s. According to the US Centers for Disease Control and Prevention (CDC) "exposure to intense, direct amounts of non-ionizing radiation may result in damage to tissue due to heat. This is not common and mainly of concern in the workplace for those who work on large sources of non-ionizing radiation devices and instruments."[189] Some advocates of fringe health claim the regulatory standards are too low and influenced by lobbying groups.[190] An anti-5G sticker in Luxembourg There have been rumors that 5G mobile phone use can cause cancer, but this is a myth.[191] Many popular books of dubious merit have been published on the subject[additional citation(s) needed] including one by Joseph Mercola alleging that wireless technologies caused numerous conditions from ADHD to heart diseases and brain cancer. Mercola has drawn sharp criticism for his anti-vaccinationism during the COVID-19 pandemic and was warned by the Food and Drug Administration to stop selling fake COVID-19 cures through his online alternative medicine business.[190][192] According to The New York Times, one origin of the 5G health controversy was an erroneous unpublished study that physicist Bill P. Curry did for the Broward County School Board in 2000 which indicated that the absorption of external microwaves by brain tissue increased with frequency.[193] According to experts[vague] this was wrong, the millimeter waves used in 5G are safer than lower frequency microwaves because they cannot penetrate the skin and reach internal organs. Curry had confused in vitro and in vivo research. However Curry's study was widely distributed on the Internet. Writing in The New York Times in 2019, William Broad reported that RT America began airing programming linking 5G to harmful health effects which "lack scientific support", such as "brain cancer, infertility, autism, heart tumors, and Alzheimer's disease". Broad asserted that the claims had increased. RT America had run seven programs on this theme by mid-April 2019 but only one in the whole of 2018. The network's coverage had spread to hundreds of blogs and websites.[194] In April 2019, the city of Brussels in Belgium blocked a 5G trial because of radiation rules.[195] In Geneva, Switzerland, a planned upgrade to 5G was stopped for the same reason.[196] The Swiss Telecommunications Association (ASUT) has said that studies have been unable to show that 5G frequencies have any health impact.[197] According to CNET,[198] "Members of Parliament in the Netherlands are also calling on the government to take a closer look at 5G. Several leaders in the United States Congress have written to the Federal Communications Commission expressing concern about potential health risks. In Mill Valley, California, the city council blocked the deployment of new 5G wireless cells."[199][200][201][202] Similar concerns were raised in Vermont[203] and New Hampshire.[198] The US FDA is quoted saying that it "continues to believe that the current safety limits for cellphone radiofrequency energy exposure remain acceptable for protecting the public health".[204] After campaigning by activist groups, a series of small localities in the UK, including Totnes, Brighton and Hove, Glastonbury, and Frome, passed resolutions against the implementation of further 5G infrastructure, though these resolutions have no impact on rollout plans.[205][206][207] Low-level EMF does have some effects on other organisms.[208] Vian et al., 2006 finds an effect of microwave on gene expression in plants.[209] A meta-analysis of 95 in vitro and in vivo studies showed that an average of 80% of the in vivo research showed effects of such radiation, as did 58% of the in vitro research, but that the results were inconclusive as to whether any of these effects pose a health risk.[209] Main article: COVID-19 misinformation § 5G mobile phone networks The World Health Organization published a mythbuster infographic to combat the conspiracy theories about COVID-19 and 5G As the introduction of 5G technology coincided with the time of the COVID-19 pandemic, several conspiracy theories circulating online posited a link between COVID-19 and 5G.[210] This has led to dozens of arson attacks being made on telecom masts in the Netherlands (Amsterdam, Rotterdam, etc.), Ireland (Cork,[211] etc.), Cyprus, the United Kingdom (Dagenham, Huddersfield, Birmingham, Belfast and Liverpool),[212][213] Belgium (Pelt), Italy (Maddaloni), Croatia (Bibinje)[214] and Sweden.[215] It led to at least 61 suspected arson attacks against telephone masts in the United Kingdom alone[216] and over twenty in The Netherlands. In the early months of the pandemic, anti-lockdown protesters at protests over responses to the COVID-19 pandemic in Australia were seen with anti-5G signs, an early sign of what became a wider campaign by conspiracy theorists to link the pandemic with 5G technology. There are two versions of the 5G-COVID-19 conspiracy theory:[190] The first version claims that radiation weakens the immune system, making the body more vulnerable to SARS-CoV-2 (the virus that causes COVID-19). The second version claims that 5G causes COVID-19. There are different variations on this. Some claim that the pandemic is coverup of illness caused by 5G radiation or that COVID-19 originated in Wuhan because that city was "the guinea-pig city for 5G". Main articles: 5G Evolution, LTE Advanced Pro, and LTE AdvancedThis section needs expansion. You can help by adding to it. (October 2023) In various parts of the world, carriers have launched numerous differently branded technologies, such as "5G Evolution", which advertise improving existing networks with the use of "5G technology".[217] However, these pre-5G networks are an improvement on specifications of existing LTE networks that are not exclusive to 5G. While the technology promises to deliver higher speeds, and is described by AT&T as a "foundation for our evolution to 5G while the 5G standards are being finalized", it cannot be considered to be true 5G. When AT&T announced 5G Evolution, 4x4 MIMO, the technology that AT&T is using to deliver the higher speeds, had already been put in place by T-Mobile without being branded with the 5G moniker. It is claimed that such branding is a marketing move that will cause confusion with consumers, as it is not made clear that such improvements are not true 5G.[218] With the rollout of 5G, 4G has become more accessible and affordable, with the world's best covered country being Norway having >90% LTE coverage.[219] Because of this, 4G is still not obsolete even today.[220] 4G plans are sold alongside 5G plans on US carriers,[221] with 4G being cheaper than 5G.[222] This section needs to be updated. Please help update this article to reflect recent events or newly available information. (April 2019) Cellular network standards and generation timeline. In April 2008, NASA partnered with Geoff Brown and Machine-to-Machine Intelligence (M2Mi) Corp to develop a fifth generation communications technology approach, though largely concerned with working with nanosats.[223] That same year, the South Korean IT R&D program of "5G mobile communication systems based on beam-division multiple access and relays with group cooperation" was formed.[224] In August 2012, New York University founded NYU Wireless, a multi-disciplinary academic research centre that has conducted pioneering work in 5G wireless communications.[225] On October 8, 2012, the UK's University of Surrey secured £35M for a new 5G research centre, jointly funded by the British government's UK Research Partnership Investment Fund (UKRPIF) and a consortium of key international mobile operators and infrastructure providers, including Huawei, Samsung, Telefónica Europe, Fujitsu Laboratories Europe, Rohde & Schwarz, and Aircom International. It will offer testing facilities to mobile operators keen to develop a mobile standard that uses less energy and less radio spectrum, while delivering speeds higher than current 4G with aspirations for the new technology to be ready within a decade.[226][227][228][229] On November 1, 2012, the EU project "Mobile and wireless communications Enablers for the Twenty-twenty Information Society" (METIS) started its activity towards the definition of 5G. METIS achieved an early global consensus on these systems. In this sense, METIS played an important role in building consensus among other external major stakeholders prior to global standardization activities. This was done by initiating and addressing work in relevant global fora (e.g. ITU-R), as well as in national and regional regulatory bodies.[230] That same month, the iJOIN EU project was launched, focusing on "small cell" technology, which is of key importance for taking advantage of limited and strategic resources, such as the radio wave spectrum. According to Günther Oettinger, the European Commissioner for Digital Economy and Society (2014–2019), "an innovative utilization of spectrum" is one of the key factors at the heart of 5G success. Oettinger further described it as "the essential resource for the wireless connectivity of which 5G will be the main driver".[231] iJOIN was selected by the European Commission as one of the pioneering 5G research projects to showcase early results on this technology at the Mobile World Congress 2015 (Barcelona, Spain). In February 2013, ITU-R Working Party 5D (WP 5D) started two study items: (1) Study on IMT Vision for 2020 and beyond, and; (2) Study on future technology trends for terrestrial IMT systems. Both aiming at having a better understanding of future technical aspects of mobile communications toward the definition of the next generation mobile.[232] On May 12, 2013, Samsung Electronics stated that they had developed a "5G" system. The core technology has a maximum speed of tens of Gbit/s (gigabits per second). In testing, the transfer speeds for the "5G" network sent data at 1.056 Gbit/s to a distance of up to 2 kilometers with the use of an 8*8 MIMO.[233][234] In July 2013, India and Israel agreed to work jointly on development of fifth generation (5G) telecom technologies.[235] On October 1, 2013, NTT (Nippon Telegraph and Telephone), the same company to launch world's first 5G network in Japan, wins Minister of Internal Affairs and Communications Award at CEATEC for 5G R&D efforts.[236] On November 6, 2013, Huawei announced plans to invest a minimum of $600 million into R&D for next generation 5G networks capable of speeds 100 times higher than modern LTE networks.[237] On April 3, 2019, South Korea became the first country to adopt 5G.[238] Just hours later, Verizon launched its 5G services in the United States, and disputed South Korea's claim of becoming the world's first country with a 5G network, because allegedly, South Korea's 5G service was launched initially for just six South Korean celebrities so that South Korea could claim the title of having the world's first 5G network.[239] In fact, the three main South Korean telecommunication companies (SK Telecom, KT, and LG Uplus) added more than 40,000 users to their 5G network on the launch day.[240] In June 2019, the Philippines became the first country in Southeast Asia to roll out a 5G broadband network after Globe Telecom commercially launched its 5G data plans to customers.[241] AT&T brings 5G service to consumers and businesses in December 2019 ahead of plans to offer 5G throughout the United States in the first half of 2020.[242][243][244] In 2020, AIS and TrueMove H launched 5G services in Thailand, making it the first country in Southeast Asia to cover 5G services in Thailand.[245][246] A functional mockup of a Russian 5G base station, developed by domestic specialists as part of Rostec's digital division Rostec.digital, was presented in Nizhny Novgorod at the annual conference "Digital Industry of Industrial Russia".[247][248] 5G speeds have declined in many countries since 2022, which has driven the development of 5.5G to increase connection speeds.[249] ^ When there's only one network. ^ Hoffman, Chris (January 7, 2019). 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This generation was characterized by the use of analog audio transmissions, a major distinction from the subsequent 2G networks, which were fully digital. The term "1G" itself was not used at the time, but has since been retroactively applied to describe the early era of cellular networks. During the 1G era, various regional standards were developed and deployed in different countries, rather than a single global system. Among the most prominent were the Nordic Mobile Telephone (NMT) system and the Advanced Mobile Phone System (AMPS), which were widely adopted in their respective regions.[1] The lack of a unified global standard resulted in a fragmented landscape, with different countries and regions utilizing different technologies for mobile communication. As digital technology advanced, the inherent advantages of digital systems over analog led to the eventual replacement of 1G by 2G networks. While many 1G networks were phased out by the early 2000s, some continued to operate into the 2010s, particularly in less developed regions. The antecedent to 1G technology is the mobile radio telephone (i.e. "0G"), where portable phones would connect to a centralised operator. 1G refers to the very first generation of cellular networks.[2] Cellular technology employ a network of cells throughout a geographical area using low-power radio transmitters.[1] Cellular network standards and generation timeline. The first commercial cellular network was launched in Japan by Nippon Telegraph and Telephone (NTT) in 1979, initially in the metropolitan area of Tokyo. The first phone that used this network was called TZ-801 built by Panasonic.[3] Within five years, the NTT network had been expanded to cover the whole population of Japan and became the first nationwide 1G/cellular network. Before the network in Japan, Bell Laboratories built the first cellular network around Chicago in 1977 and trialled it in 1978.[4] As in the pre-cellular era, the Nordic countries were among the pioneers in wireless technologies. These countries together designed the NMT standard which first launched in Sweden in 1981.[5] NMT was the first mobile phone network to feature international roaming. In 1983, the first 1G cellular network launched in the United States, which was Chicago-based Ameritech using the Motorola DynaTAC mobile phone. In the early to mid 1990s, 1G was superseded by newer 2G (second generation) cellular technologies such as GSM and cdmaOne. Although 1G also used digital signaling to connect the radio towers (which listen to the handsets) to the rest of the telephone system, the voice itself during a call is encoded to digital signals in 2G whereas 1G uses analog FM modulation for the voice transmission, much like a 2-way land mobile radio. Most 1G networks had been discontinued by the early 2000s. Some regions especially Eastern Europe continued running these networks for much longer. The last operating 1G network was closed down in Russia in 2017. After Japan, the earliest commercial cellular networks launched in 1981 in Sweden, Norway and Saudi Arabia, followed by Denmark, Finland and Spain in 1982, the U.S. in 1983 and Hong Kong, South Korea, Austria and Canada in 1984. By 1986 networks had also launched in Tunisia, Malaysia, Oman, Ireland, Italy, Luxembourg, Netherlands, United Kingdom, West Germany, France, South Africa, Israel, Thailand, Indonesia, Iceland, Turkey, the Virgin Islands and Australia.[6] Generally, African countries were slower to take up 1G networks, while Eastern European were among the last due to the political situation.[7] In Europe, the United Kingdom had the largest number of cellular subscribers as of 1990 numbering 1.1 million, while the second largest market was Sweden with 482 thousand.[7] Although Japan was the first country with a nationwide cellular network, the number of users was significantly lower than other developed economies with a penetration rate of only 0.15 percent in 1989.[5] As of January 1991, the highest penetration rates were in Sweden and Finland with both countries above 50 percent closely followed by Norway and Iceland. The United States had a rate of 21.2 percent. In most other European countries it was below 10 percent.[8] Analog cellular technologies that were used were:[6] Advanced Mobile Phone System (AMPS)[9] Nordic Mobile Telephone (NMT) Total Access Communication System (TACS) developed in the United Kingdom and also some other parts of the world C-450 developed in West Germany and also adopted in Portugal and South Africa Radiocom 2000 in France (France Telecom only) RTMI in Italy MCS-L1 and MCS-L2 (developed by NTT) in Japan[10] JTACS (a variant of TACS operated by Daini Denden Planning, Inc. (DDI)) in Japan[10] List of mobile phone generations 2G 3G 3.5G 4G 4.5G 5G 6G Wireless Application Protocol Wireless device radiation and health ^ a b "Chapter 3 - Technology". 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Glossary: 1G – First Generation wireless technology Glossary: Detailed Description on 1G Technology Preceded by0G Mobile Telephony Generations Succeeded by2G Retrieved from " 4First generation of digital cellular networks For other uses, see 2G (disambiguation). Part of a series on theWireless network technologies Analog 0G1G (1.5G) Digital 2G (2.5G, 2.75G, 2.9G)3G (3.5G, 3.75G, 3.9G/3.95G)4G (4G/4.5G, 4.5G, 4.9G)5G (5.5G)6G Mobile telecommunicationsvte 2G refers to the second-generation of cellular network technology, which were rolled out globally starting in the early 1990s. The main differentiator to previous mobile telephone systems, retrospectively dubbed 1G, is that the radio signals of 2G networks are digital rather than analog, for communication between mobile devices and base stations. In addition to voice telephony, 2G also made possible the use of data services. The most common 2G technology has been the GSM standard, which became the first globally adopted framework for mobile communications. Other 2G technologies include cdmaOne and the now-discontinued Digital AMPS (D-AMPS/TDMA),[1] as well the Personal Digital Cellular (PDC) and Personal Handy-phone System (PHS) in Japan. The transition to digital technology enabled the implementation of encryption for voice calls and data transmission, significantly improving the security of mobile communications while also increasing capacity and efficiency compared to earlier analog systems. 2G networks were primarily designed to support voice calls and Short Message Service (SMS), with later advancements such as General Packet Radio Service (GPRS) enabling always-on packet data services, including email and limited internet access. 2G was succeeded by 3G technology, which provided higher data transfer rates and expanded mobile internet capabilities. In 1990, AT&T Bell Labs engineers Jesse Russell, Farhad Barzegar and Can A. Eryaman filed a patent for a digital mobile phone that supports the transmission of digital data. Their patent was cited several years later by Nokia and Motorola when they were developing 2G digital mobile phones.[2] 2G was first commercially launched in 1991 by Radiolinja (now part of Elisa Oyj) in Finland in the form of GSM, which was defined by the European Telecommunications Standards Institute (ETSI).[3] The Telecommunications Industry Association (TIA) defined the cdmaOne (IS-95) 2G standard, with an eight to ten fold increase in voice call capacity compared to analog AMPS.[4] The first deployment of cdmaOne was in 1995.[5] In North America, Digital AMPS (IS-54 and IS-136) and cdmaOne (IS-95) were dominant, but GSM was also used. Later 2G releases in the GSM space, often referred to as 2.5G and 2.75G, include General Packet Radio Service (GPRS) and Enhanced Data Rates for GSM Evolution (EDGE). GPRS allows 2G networks to achieve a theoretical maximum transfer speed of 40 kbit/s (5 kB/s). EDGE increases this capacity, providing a theoretical maximum transfer speed of 384 kbit/s (48 kB/s). Three primary benefits of 2G networks over their 1G predecessors were: Digitally encrypted phone conversations, at least between the mobile phone and the cellular base station but not necessarily in the rest of the network. Significantly more efficient use of the radio frequency spectrum enabling more users per frequency band. Data services for mobile, starting with SMS text messages then expanding to Multimedia Messaging Service (MMS). Cellular network standards and generation timeline. (Large titles on the colored area refer to the lines to their right. Main article: GPRS 2.5G ("second-and-a-half generation") refers to 2G systems that incorporate a packet-switched domain alongside the existing circuit-switched domain, most commonly implemented through General Packet Radio Service (GPRS).[6] GPRS enables packet-based data transmission by dynamically allocating multiple timeslots to users, improving network efficiency. However, this does not inherently provide faster speeds, as similar techniques, such as timeslot bundling, are also employed in circuit-switched data services like High-Speed Circuit-Switched Data (HSCSD). Within GPRS-enabled 2G systems, the theoretical maximum transfer rate is 40 kbit/s (5 kB/s).[7] Main article: EDGE 2.75G refers to the evolution of GPRS networks into EDGE (Enhanced Data Rates for GSM Evolution) networks, achieved through the introduction of 8PSK (8 Phase Shift Keying) encoding. While the symbol rate remained constant at 270.833 samples per second, the use of 8PSK allowed each symbol to carry three bits instead of one, significantly increasing data transmission efficiency. Enhanced Data Rates for GSM Evolution (EDGE), also known as Enhanced GPRS (EGPRS) or IMT Single Carrier (IMT-SC), is a backward-compatible digital mobile phone technology built as an extension to standard GSM. First deployed in 2003 by AT&T in the United States, EDGE offers a theoretical maximum transfer speed of 384 kbit/s (48 kB/s).[7] Evolved EDGE (also known as EDGE Evolution or 2.875G) is an enhancement of the EDGE mobile technology that was introduced as a late-stage upgrade to 2G networks. While EDGE was first deployed in the early 2000s as part of GSM networks, Evolved EDGE was launched much later, coinciding with the widespread adoption of 3G technologies such as HSPA and just before the emergence of 4G networks. This timing limited its practical application. Evolved EDGE increased data throughput and reduced latencies (down to 80 ms) by utilizing improved modulation techniques, dual carrier support, dual antennas, and turbo codes. It achieved peak data rates of up to 1 Mbit/s, significantly enhancing network efficiency for operators that had not yet transitioned to 3G or 4G infrastructures. However, despite its technical improvements, Evolved EDGE was never widely deployed. By the time it became available, most network operators were focused on implementing more advanced technologies like UMTS and LTE. As of 2016, no commercial networks were reported to support Evolved EDGE. See also: GSM § Discontinuation 2G, understood as GSM and CdmaOne, has been superseded by newer technologies such as 3G (UMTS / CDMA2000), 4G (LTE / WiMAX) and 5G (5G NR). However, 2G networks were still available as of 2023[update] in most parts of the world, while notably excluding the majority of carriers in North America, East Asia, and Australasia.[8][9][10] Many modern LTE-enabled devices have the ability to fall back to 2G for phone calls, necessary especially in rural areas where later generations have not yet been implemented.[11] In some places, its successor 3G is being shut down rather than 2G – Vodafone previously announced that it had switched off 3G across Europe in 2020 but still retains 2G as a fallback service.[12] In the US T-Mobile shut down their 3G services while retaining their 2G GSM network.[13][14] Various carriers have made announcements that 2G technology in the United States, Japan, Australia, and other countries are in the process of being shut down, or have already shut down 2G services so that carriers can re-use the frequencies for newer technologies (e.g. 4G, 5G).[15][16] As a legacy protocol, 2G connectivity is considered insecure.[17] Specifically, there exist well known methods to attack weaknesses in GSM since 2009[18] with practical use in crime.[19] Attack routes on 2G CdmaOne were found later and remain less publicized.[20] Android 12 and later provide a network setting to disable 2G connectivity for the device.[21] iOS 16 and later can disable 2G connectivity by enabling Lockdown Mode.[22] In some parts of the world, including the United Kingdom, 2G remains widely used for older feature phones and for internet of things (IoT) devices such as smart meters, eCall systems and vehicle trackers to avoid the high patent licensing cost of newer technologies.[23] Terminating 2G services could leave vulnerable people who rely on 2G infrastructure unable to communicate even with emergency contacts, causing harm and possibly deaths.[24] Country Status Network Shutdown date Standard Notes Åland Ålcom 2024 GSM 2G availability cannot be guaranteed after 1 Jan 2022, all stations are planned to be shut down in 2024.[25] Anguilla Digicel active GSM 900 MHz: 5 MHz GSM + 5 MHz UMTS1900 MHz: 5 MHz UMTS [26][27][28][29] FLOW 2024-04-22 GSM [30][31] Antigua and Barbuda No Service APUA 2018-04-01 GSM [32] Digicel 2024-05-31 GSM [33] FLOW 2024-07-31 GSM [34] Aruba partiallyunconfirmed Digicel 2024-06-30 GSM [35] SETAR active GSM GSM-900 & GSM-1900 Australia No Service Hutchison 3 2006-08-09 cdmaOne [36][37][38][39][40] Optus 2017-08-01 GSM 2G shut down in WA and NT on 3 Apr 2017.[41][42] Telstra 2008-04-28 cdmaOne [43][44][45][46][47] Telstra 2016-12-01 GSM [48] Vodafone 2018-06-14 GSM [49] Bahamas No Service Aliv N/A (no 2G) BTC 2024-06-30 GSM [50][51][52] Bahrain Batelco 2021-11-30 GSM [53] Barbados partiallyunconfirmed Digicel 2025-03-31 GSM 900 MHz: 6 MHz GSM /1800 MHz: 12 MHz GSM [54] FLOW 2024-04-22 GSM Belgium Orange 2030 GSM [55] Telenet 2027 GSM [56] Proximus 2027 GSM [57] Bermuda Digicel active GSM 1900 MHz: 15 MHz GSM + 15 MHz LTE [58] One active GSM 1900 MHz: 5 MHz GSM + 20 MHz LTE [58] Bonaire partiallyunconfirmed Digicel 2025-03-31 GSM FLOW 2024-04-22 GSM British Virgin Islands CCT active GSM 1900 MHz: 10 MHz GSM + 20 MHz LTE [59] Digicel active GSM 1800 MHz: 15 MHz GSM1900 MHz: 5 MHz GSM + 10 MHz UMTS [59] FLOW 2024-04-22 GSM [60] Brunei No Service UNN 2021-06-01 GSM National Wholesale Network used by DSTCom, Progresif and imagine.[61][62] Canada Bell 2019-04-30 cdmaOne Shutdown of CDMA transmitters commenced in remote areas in 2017, followed by an official announcement in June 2018 that 2G devices will lose service soon.[63][64] Rogers Wireless TBD GSM 1900 MHz shutdown in Jun 2021.850 MHz remains active.[65][66][67][68] SaskTel 2017-07-31 cdmaOne [69][70] Telus Mobility 2017-05-31 cdmaOne [71][72] Cayman Islands partiallyunconfirmed Digicel 2020-07-01 GSM [73][74] FLOW 2024-04-22 GSM China China Mobile active GSM 900 MHz: 15 MHz GSM1800 MHz: 25 MHz GSM [75] China Telecom 2025 cdmaOne Local shutdown commenced on 01 Jun 2020.CDMA2000 1xRTT, EV-DO Rev. 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Government originally did not allow the license to be renewed due to unpopularity, however the government later reversed the decision and held an auction for CDMA2000 service, which PCCW-HKT won the auction and provided CDMA2000 service immediately after 3's license expiry. 3 2021-09-30 GSM [92] CMHK active GSM 1800 MHz only CSL 2005 D-AMPS Service previously provided by Pacific Link, which subsequently merged into CSL. Shut down due to license expiry. Government did not allow the license to be renewed due to unpopularity. CSL 2017-10-31 cdmaOne Service previously provided by PCCW. After acquisition of CSL by HKT, its mobile business PCCW Mobile was merged into CSL. No service for local customers, only served incoming roaming tourists.CSL terminated its CDMA family business upon its licence expiry, and CDMA2000 1xRTT, EV-DO Rev. 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Retrieved 3 April 2025. ^ a b c d "2G network switched off by the end of October 15". VnEconomy. 17 September 2024. Retrieved 12 October 2024. Preceded by1st Generation (1G) Mobile Telephony Generations Succeeded by3rd Generation (3G) Retrieved from " 5Third generation of wireless mobile telecommunications technology For other uses, see 3G (disambiguation). This article needs to be updated. Please help update this article to reflect recent events or newly available information. (April 2021) A USB modem for 3G plugged into a laptop. Part of a series on theWireless network technologies Analog 0G1G (1.5G) Digital 2G (2.5G, 2.75G, 2.9G)3G (3.5G, 3.75G, 3.9G/3.95G)4G (4G/4.5G, 4.5G, 4.9G)5G (5.5G)6G Mobile telecommunicationsvte 3G refers to the third-generation of cellular network technology. These networks were rolled out beginning in the early 2000s and represented a significant advancement over the second-generation (2G), particularly in terms of data transfer speeds and mobile internet capabilities. The major 3G standards are UMTS (developed by 3GPP, succeeding GSM) and CDMA2000 (developed by Qualcomm, succeeding cdmaOne);[1][2] both of these are based on the IMT-2000 specifications established by the International Telecommunication Union (ITU). While 2G networks such as GPRS and EDGE supported limited data services, 3G introduced significantly higher-speed mobile internet and enhanced multimedia capabilities, in addition to improved voice quality.[3] It provided moderate internet speeds suitable for general web browsing and multimedia content including video calling and mobile TV,[3] supporting services that provide an information transfer rate of at least 144 kbit/s.[4][5] Later 3G releases, often referred to as 3.5G (HSPA) and 3.75G (HSPA+) as well as EV-DO, introduced important improvements, enabling 3G networks to offer mobile broadband access with speeds ranging from several Mbit/s up to 42 Mbit/s.[6] These updates improved the reliability and speed of internet browsing, video streaming, and online gaming, enhancing the overall user experience for smartphones and mobile modems in comparison to earlier 3G technologies. 3G was later succeeded by 4G technology, which provided even higher data transfer rates and introduced advancements in network performance. A new generation of cellular standards has emerged roughly every decade since the introduction of 1G systems in 1979. Each generation is defined by the introduction of new frequency bands, higher data rates, and transmission technologies that are not backward-compatible due to the need for significant changes in network architecture and infrastructure. Several telecommunications companies marketed wireless mobile Internet services as 3G, indicating that the advertised service was provided over a 3G wireless network. However, 3G services have largely been supplanted in marketing by 4G and 5G services in most areas of the world. Services advertised as 3G are required to meet IMT-2000 technical standards, including standards for reliability and speed (data transfer rates). To meet the IMT-2000 standards, Third-generation mobile networks, or 3G, must maintain minimum consistent Internet speeds of 144 Kbps.[5] However, many services advertised as 3G provide higher speed than the minimum technical requirements for a 3G service.[7] Subsequent 3G releases, denoted 3.5G and 3.75G, provided mobile broadband access of several Mbit/s for smartphones and mobile modems in laptop computers.[8] 3G branded standards: The UMTS (Universal Mobile Telecommunications System) system, standardized by 3GPP in 2001, was used in Europe, Japan, China (with a different radio interface) and other regions predominated by GSM (Global Systems for Mobile Communications) 2G system infrastructure. The cell phones are typically UMTS and GSM hybrids. Several radio interfaces are offered, sharing the same infrastructure: The original and most widespread radio interface is called W-CDMA (Wideband Code Division Multiple Access). The TD-SCDMA radio interface was commercialized in 2009 and only offered in China. The latest UMTS release, HSPA+, can provide peak data rates up to 56 Mbit/s in the downlink in theory (28 Mbit/s in existing services) and 22 Mbit/s in the uplink. The CDMA2000 system, first offered in 2002, standardized by 3GPP2, used especially in North America and South Korea, sharing infrastructure with the IS-95 2G standard. The cell phones are typically CDMA2000 and IS-95 hybrids. The latest release EVDO Rev. B offers peak rates of 14.7 Mbit/s downstream. The 3G systems and radio interfaces are based on spread spectrum radio transmission technology. While the GSM EDGE standard ("2.9G"), DECT cordless phones and Mobile WiMAX standards formally also fulfill the IMT-2000 requirements and are approved as 3G standards by ITU, these are typically not branded as 3G and are based on completely different technologies. The common standards complying with the IMT2000/3G standard are: EDGE, a revision by the 3GPP organization to the older 2G GSM based transmission methods, which utilizes the same switching nodes, base station sites, and frequencies as GPRS, but includes a new base station and cellphone RF circuits. It is based on the three times as efficient 8PSK modulation scheme as a supplement to the original GMSK modulation scheme. EDGE is still used extensively due to its ease of upgrade from existing 2G GSM infrastructure and cell phones. EDGE combined with the GPRS 2.5G technology is called EGPRS, and allows peak data rates in the order of 200 kbit/s, just like the original UMTS WCDMA versions and thus formally fulfill the IMT2000 requirements on 3G systems. However, in practice, EDGE is seldom marketed as a 3G system, but a 2.9G system. EDGE shows slightly better system spectral efficiency than the original UMTS and CDMA2000 systems, but it is difficult to reach much higher peak data rates due to the limited GSM spectral bandwidth of 200 kHz, and it is thus a dead end. EDGE was also a mode in the IS-136 TDMA system, no longer used. Evolved EDGE, the latest revision, has peaks of 1 Mbit/s downstream and 400 kbit/s upstream but is not commercially used. The Universal Mobile Telecommunications System, created and revised by the 3GPP. The family is a full revision from GSM in terms of encoding methods and hardware, although some GSM sites can be retrofitted to broadcast in the UMTS/W-CDMA format. W-CDMA is the most common deployment, commonly operated on the 2,100 MHz band. A few others use the 850, 900, and 1,900 MHz bands. HSPA is an amalgamation of several upgrades to the original W-CDMA standard and offers speeds of 14.4 Mbit/s down and 5.76 Mbit/s up. HSPA is backward-compatible and uses the same frequencies as W-CDMA. HSPA+, a further revision and upgrade of HSPA, can provide theoretical peak data rates up to 168 Mbit/s in the downlink and 22 Mbit/s in the uplink, using a combination of air interface improvements as well as multi-carrier HSPA and MIMO. Technically though, MIMO and DC-HSPA can be used without the "+" enhancements of HSPA+. The CDMA2000 system, or IS-2000, including CDMA2000 1x and CDMA2000 High Rate Packet Data (or EVDO), standardized by 3GPP2 (differing from the 3GPP), evolving from the original IS-95 CDMA system, is used especially in North America, China, India, Pakistan, Japan, South Korea, Southeast Asia, Europe, and Africa. CDMA2000 1x Rev. E has an increased voice capacity (by three times the original amount) compared to Rev. 0 EVDO Rev. B offers downstream peak rates of 14.7 Mbit/s while Rev. C enhanced existing and new terminal user experience. While DECT cordless phones and Mobile WiMAX standards formally also fulfill the IMT-2000 requirements, they are not usually considered due to their rarity and unsuitability for usage with mobile phones.[9] The 3G (UMTS and CDMA2000) research and development projects started in 1992. In 1999, ITU approved five radio interfaces for IMT-2000 as a part of the ITU-R M.1457 Recommendation; WiMAX was added in 2007.[10] There are evolutionary standards (EDGE and CDMA) that are backward-compatible extensions to pre-existing 2G networks as well as revolutionary standards that require all-new network hardware and frequency allocations. The cell phones use UMTS in combination with 2G GSM standards and bandwidths, but do not support EDGE. The latter group is the UMTS family, which consists of standards developed for IMT-2000, as well as the independently developed standards DECT and WiMAX, which were included because they fit the IMT-2000 definition. While EDGE fulfills the 3G specifications, most GSM/UMTS phones report EDGE ("2.75G") and UMTS ("3G") functionality.[11] Cellular network standards and generation timeline. 3G technology was the result of research and development work carried out by the International Telecommunication Union (ITU) in the early 1980s. 3G specifications and standards were developed in fifteen years. The technical specifications were made available to the public under the name IMT-2000. The communication spectrum between 400 MHz to 3 GHz was allocated for 3G. Both the government and communication companies approved the 3G standard. The first pre-commercial 3G network was launched by NTT DoCoMo in Japan in 1998,[12] branded as FOMA. It was first available in May 2001 as a pre-release (test) of W-CDMA technology. The first commercial launch of 3G was also by NTT DoCoMo in Japan on 1 October 2001, although it was initially somewhat limited in scope;[13][14] broader availability of the system was delayed by apparent concerns over its reliability.[15][16][17][18][19] The first European pre-commercial network was an UMTS network on the Isle of Man by Manx Telecom, the operator then owned by British Telecom, and the first commercial network (also UMTS based W-CDMA) in Europe was opened for business by Telenor in December 2001 with no commercial handsets and thus no paying customers. The first network to go commercially live was by SK Telecom in South Korea on the CDMA-based 1xEV-DO technology in January 2002. By May 2002, the second South Korean 3G network was by KT on EV-DO and thus the South Koreans were the first to see competition among 3G operators. The first commercial United States 3G network was by Monet Mobile Networks, on CDMA2000 1x EV-DO technology, but the network provider later shut down operations. The second 3G network operator in the US was Verizon Wireless in July 2002, also on CDMA2000 1x EV-DO. AT&T Mobility was also a true 3G UMTS network, having completed its upgrade of the 3G network to HSUPA. The first commercial United Kingdom 3G network was started by Hutchison Telecom which was originally behind Orange S.A.[20] In 2003, it announced first commercial third generation or 3G mobile phone network in the UK. The first pre-commercial demonstration network in the southern hemisphere was built in Adelaide, South Australia, by m.Net Corporation in February 2002 using UMTS on 2100 MHz. This was a demonstration network for the 2002 IT World Congress. The first commercial 3G network was launched by Hutchison Telecommunications branded as Three or "3" in June 2003.[21] In India, on 11 December 2008, the first 3G mobile and internet services were launched by a state-owned company, Mahanagar Telecom Nigam Limited (MTNL), within the metropolitan cities of Delhi and Mumbai. After MTNL, another state-owned company, Bharat Sanchar Nigam Limited (BSNL), began deploying the 3G networks country-wide. Emtel launched the first 3G network in Africa.[22] Videotelephony through cellular networks were made possible using 3G technologies Japan was one of the first countries to adopt 3G, the reason being the process of 3G spectrum allocation, which in Japan was awarded without much upfront cost. The frequency spectrum was allocated in the US and Europe based on auctioning, thereby requiring a huge initial investment for any company wishing to provide 3G services. European companies collectively paid over 100 billion dollars in their spectrum auctions.[23] Nepal Telecom adopted 3G Service for the first time in southern Asia. However, its 3G was relatively slow to be adopted in Nepal. In some instances, 3G networks do not use the same radio frequencies as 2G, so mobile operators must build entirely new networks and license entirely new frequencies, especially to achieve high data transmission rates. Other countries' delays were due to the expenses of upgrading transmission hardware, especially for UMTS, whose deployment required the replacement of most broadcast towers. Due to these issues and difficulties with deployment, many carriers could not or delayed the acquisition of these updated capabilities. In December 2007, 190 3G networks were operating in 40 countries and 154 HSDPA networks were operating in 71 countries, according to the Global Mobile Suppliers Association (GSA). In Asia, Europe, Canada, and the US, telecommunication companies use W-CDMA technology with the support of around 100 terminal designs to operate 3G mobile networks. The roll-out of 3G networks was delayed by the enormous costs of additional spectrum licensing fees in some countries. The license fees in some European countries were particularly high, bolstered by government auctions of a limited number of licenses and sealed bid auctions, and initial excitement over 3G's potential. This led to a telecoms crash that ran concurrently with similar crashes in the fibre-optic and dot.com fields. The 3G standard is perhaps well known because of a massive expansion of the mobile communications market post-2G and advances of the consumer mobile phone. An especially notable development during this time is the smartphone (for example, the iPhone, and the Android family), combining the abilities of a PDA with a mobile phone, leading to widespread demand for mobile internet connectivity. 3G has also introduced the term "mobile broadband" because its speed and capability made it a viable alternative for internet browsing, and USB Modems connecting to 3G networks, and now 4G became increasingly common. By June 2007, the 200 millionth 3G subscriber had been connected of which 10 million were in Nepal and 8.2 million in India. This 200 millionth is only 6.7% of the 3 billion mobile phone subscriptions worldwide. (When counting CDMA2000 1x RTT customers—max bitrate 72% of the 200 kbit/s which defines 3G—the total size of the nearly-3G subscriber base was 475 million as of June 2007, which was 15.8% of all subscribers worldwide.) In the countries where 3G was launched first – Japan and South Korea – 3G penetration is over 70%.[24] In Europe the leading country[when?] for 3G penetration is Italy with a third of its subscribers migrated to 3G. Other leading countries[when?] for 3G use include Nepal, UK, Austria, Australia and Singapore at the 32% migration level. According to ITU estimates,[25] as of Q4 2012 there were 2096 million active mobile-broadband[vague] subscribers worldwide out of a total of 6835 million subscribers—this is just over 30%. About half the mobile-broadband subscriptions are for subscribers in developed nations, 934 million out of 1600 million total, well over 50%. Note however that there is a distinction between a phone with mobile-broadband connectivity and a smart phone with a large display and so on—although according[26] to the ITU and informatandm.com the US has 321 million mobile subscriptions, including 256 million that are 3G or 4G, which is both 80% of the subscriber base and 80% of the US population, according[25] to ComScore just a year earlier in Q4 2011 only about 42% of people surveyed in the US reported they owned a smart phone. In Japan, 3G penetration was similar at about 81%, but smart phone ownership was lower at about 17%.[25] In China, there were 486.5 million 3G subscribers in June 2014,[27] in a population of 1,385,566,537 (2013 UN estimate). Since the increasing adoption of 4G networks across the globe, 3G use has been in decline. Several operators around the world have already or are in the process of shutting down their 3G networks (see table below). In several places, 3G is being shut down while its older predecessor 2G is being kept in operation; Vodafone UK is doing this, citing 2G's usefulness as a low-power fallback.[28] EE in the UK, plans to switch off their 3G networks in early 2024.[29] In the US, Verizon shutdown their 3G services on 31 December 2022,[30] T-Mobile shut down Sprint's networks on 31 March 2022 and shutdown their main networks on 1 July 2022,[31] and AT&T has done so on 22 February 2022.[32] Currently 3G around the world is declining in availability and support. Technology that depends on 3G for usage are becoming inoperable in many places. For example, the European Union plans to ensure that member countries maintain 2G networks as a fallback[citation needed], so 3G devices that are backwards compatible with 2G frequencies can continue to be used. However, in countries that plan to decommission 2G networks or have already done so as well, such as the United States and Singapore, devices supporting only 3G and backwards compatible with 2G are becoming inoperable.[33] As of February 2022, less than 1% of cell phone customers in the United States used 3G; AT&T offered free replacement devices to some customers in the run-up to its shutdown.[34] It has been estimated that there are almost 8,000 patents declared essential (FRAND) related to the 483 technical specifications which form the 3GPP and 3GPP2 standards.[35][36] Twelve companies accounted in 2004 for 90% of the patents (Qualcomm, Ericsson, Nokia, Motorola, Philips, NTT DoCoMo, Siemens, Mitsubishi, Fujitsu, Hitachi, InterDigital, and Matsushita). Even then, some patents essential to 3G might not have been declared by their patent holders. It is believed that Nortel and Lucent have undisclosed patents essential to these standards.[36] Furthermore, the existing 3G Patent Platform Partnership Patent pool has little impact on FRAND protection because it excludes the four largest patent owners for 3G.[37][38] ITU has not provided a clear[39][vague] definition of the data rate that users can expect from 3G equipment or providers. Thus users sold 3G service may not be able to point to a standard and say that the rates it specifies are not being met. While stating in commentary that "it is expected that IMT-2000 will provide higher transmission rates: a minimum data rate of 2 Mbit/s for stationary or walking users, and 348 kbit/s in a moving vehicle,"[40] the ITU does not actually clearly specify minimum required rates, nor required average rates, nor what modes[clarification needed] of the interfaces qualify as 3G, so various[vague] data rates are sold as '3G' in the market. In a market implementation, 3G downlink data speeds defined by telecom service providers vary depending on the underlying technology deployed; up to 384 kbit/s for UMTS (WCDMA), up to 7.2 Mbit/sec for HSPA, and a theoretical maximum of 21.1 Mbit/s for HSPA+ and 42.2 Mbit/s for DC-HSPA+ (technically 3.5G, but usually clubbed under the tradename of 3G).[citation needed] See also: Mobile security § Attacks based on the GSM networks 3G networks offer greater security than their 2G predecessors. By allowing the UE (User Equipment) to authenticate the network it is attaching to, the user can be sure the network is the intended one and not an impersonator.[41] 3G networks use the KASUMI block cipher instead of the older A5/1 stream cipher. However, a number of serious weaknesses in the KASUMI cipher have been identified. In addition to the 3G network infrastructure security, end-to-end security is offered when application frameworks such as IMS are accessed, although this is not strictly a 3G property. The bandwidth and location capabilities introduced by 3G networks enabled a wide range of applications that were previously impractical or unavailable on 2G networks. Among the most significant advancements was the ability to perform data-intensive tasks, such as browsing the internet seamlessly while on the move, as well as engaging in other activities that benefited from faster data speeds and enhanced reliability. Beyond personal communication, 3G networks supported applications in various fields, including medical devices, fire alarms, and ankle monitors. This versatility marked a significant milestone in cellular communications, as 3G became the first network to enable such a broad range of use cases.[42] By expanding its functionality beyond traditional mobile phone usage, 3G set the stage for the integration of cellular networks into a wide array of technologies and services, paving the way for further advancements with subsequent generations of mobile networks. Both 3GPP and 3GPP2 are working on the extensions to 3G standards that are based on an all-IP network infrastructure and using advanced wireless technologies such as MIMO. These specifications already display features characteristic for IMT-Advanced (4G), the successor of 3G. However, falling short of the bandwidth requirements for 4G (which is 1 Gbit/s for stationary and 100 Mbit/s for mobile operation), these standards are classified as 3.9G or Pre-4G. 3GPP plans to meet the 4G goals with LTE Advanced, whereas Qualcomm has halted UMB development in favour of the LTE family.[43] On 14 December 2009, TeliaSonera announced in an official press release that "We are very proud to be the first operator in the world to offer our customers 4G services."[44] With the launch of their LTE network, initially they are offering pre-4G (or beyond 3G) services in Stockholm, Sweden and Oslo, Norway. Country Status Network Shutdown date Standard References Notes Argentina Personal TBD UMTS [45] Local shutdowns commenced in Q1 2023. Australia No Service Optus 2024-10-28 UMTS [46][47] Telstra 2024-10-28 UMTS [48][49][47] 2100 MHz band shutdown on 25 Mar 2019. TPG / Vodafone 2023-12-15 UMTS [50][51] Austria Magenta Telekom 2024 (est.) UMTS [52] Belgium Orange 2025-12-31 (est.) UMTS [53][54] Local shutdowns commenced in Jan 2024. Telenet 2024-09-30 (est.) UMTS [55] Local shutdowns commenced in Sep 2024. Proximus 2024-12-31 (est.) UMTS [56] Canada Bell 2025-12-31 (est.) UMTS [57] Rogers 2025-07-31 UMTS [57][58][59][60][61][62] 1900 MHz shutdown in Jun 2021.850 MHz remains active until 31 July 2025. Telus 2025-12-31 (est.) UMTS [57] Videotron 2025-07-31 UMTS [63] China China Mobile TBD TD-SCDMA [64][65][66][67] Local shutdowns commenced on 16 Mar 2016. China Telecom 2025 (est.) CDMA2000 [68][69][70] CDMA2000 1X, 1xEV-DO Rev. ALocal shutdowns commenced on 16 Jun 2020. China Unicom TBD UMTS [71] Local shutdowns commenced in Q4 2022. Croatia HT 2025 (est.) UMTS [72] Local shutdown commenced in Dec 2023. Czech Republic No Service O2 2021-11-30 UMTS [73] T-Mobile 2021-11-30 UMTS [73] Vodafone 2021-03-31 UMTS [74] Denmark 3 2025-12-01 (est.) UMTS [75] Local shutdown commenced in 2019. TDC TBD UMTS [76] Local shutdown commenced in 2022. TT-Netværket(Telenor, Telia) 2023-03-20 UMTS [77][78] Service on the 2100 MHz band ended in 2021.Shutdown on the 900 MHz band commenced in summer 2022. Estonia Elisa 2024-11-26 UMTS [79] Tele2 2025-12-31 (est.) UMTS [80] Telia Eesti 2023-12-13 UMTS [81][82][83][84] Finland No Service DNA 2024-01-25 UMTS [85][86][87][88] Local shutdowns commenced in May 2023. Elisa 2023-11-30 UMTS [89] Local shutdowns commenced in Apr 2023. Finnish Shared Network [fi] 2024-12 UMTS [90] Joint company by Telia and DNA to manage networks in Northern and Eastern Finland. Telia 2024-10-28 UMTS [91][92][93] Local shutdowns commenced on 9 Sep 2023. France Bouygues 2029 (est.) UMTS [94] Orange 2028-12-31 (est.) UMTS [53] SFR 2028 (est.) UMTS [95] Germany No Service Deutsche Telekom 2021-07-01 UMTS [96] O2 2021-12-31 UMTS [97][98][99] Vodafone 2021-06-30 UMTS [100] Greece No Service Cosmote 2021-12-31 UMTS [101] NOVA 2023-03-27 UMTS [102][103][104][105] Vodafone 2023-05-31 UMTS [106] Greenland Tusass TBD UMTS [107] Hong Kong 3 active UMTS CMHK 2025-06-30 (est.) UMTS [108] CSL 2017-10-31 CDMA2000 [109] CDMA2000 1X, 1xEV-DO Rev. A.Service previously provided by PCCW. After acquisition of CSL by HKT,its mobile business PCCW Mobile was merged into CSL.No service for local customers, only served incoming roaming tourists.CSL terminated its CDMA family business upon its licence expiry,and cdmaOne service has also terminated along with CDMA2000. CSL active UMTS Smartone active UMTS Hungary No Service Magyar Telekom 2022-06-30 UMTS [110][111][112] Yettel Hungary 2023-11-13 UMTS [110][112][113] Vodafone Hungary 2023-03-31 UMTS [114][112] Iceland Nova 2025-12-31 (est.) UMTS [115][116] Síminn 2025-12-31 (est.) UMTS [116] Vodafone 2025-12-31 (est.) UMTS [116] India Airtel 2020-03-31 UMTS [117][118] Vodafone Idea 2022-10-06 UMTS [119] Complete network refarming to 4G/LTE. Indonesia Smartfren 2017-11-13 CDMA2000 [120] CDMA2000 1X, 1xEV-DO Rel. 0, 1xEV-DO Rev. A, EV-DO Rev. B Telkomsel 2023-06-23 UMTS [121] Indosat 2022-12-31 UMTS [122] XL Axiata TBD UMTS [123][124] Local shutdowns commenced in June 2021. Ireland Vodafone TBD UMTS [125] Local shutdowns commenced in Feb 2023. Israel 2025-12-31 (est.) [126] Per government statement Italy Iliad 2025 (est.) UMTS [127] TIM 2022-10-21 UMTS [128][129][130][131] Vodafone 2021-02-28 UMTS [132] Wind Tre 2025 (est.) UMTS [127] Japan KDDI 2022-03-31 CDMA2000 [133][134][135] CDMA2000 1X, 1xEV-DO Rel. 0, 1xEV-DO Rev. A, EV-DO Rev. B NTT docomo 2026-03-31 (est.) UMTS [136] Softbank 2024-04-15 UMTS [137][138][139] Kazakhstan Tele2 TBD UMTS [140][141] Local shutdown commenced on 28 Mar 2024. Lithuania Telia 2022-12-15 UMTS [142][143][144] Tele2 2025-12 (est.) UMTS [145] Luxembourg Orange 2025-12-31 (est.) UMTS [53] Tango / Telindus 2024-01-31 UMTS [146] Macau China Telecom 2025-06-04 (est.) CDMA2000 [147][148][149] CDMA2000 1X, 1xEV-DO Rev. A CTM 2025-06-04 (est.) UMTS [149] 3 2025-06-04 (est.) UMTS [149] Smartone 2024-11-11 UMTS [150] Smartone ceased operations in Macau and returned its license. Malaysia No Service Celcom 2021-12-31 UMTS [151][152] Maxis 2021-12-31 UMTS [153] U Mobile 2021-12-31 UMTS [153] Digi 2021-12-31 UMTS [153][152] Moldova Interdnestrcom 2023-08-01 CDMA2000 [154] Montenegro Crnogorski Telekom 2024-01-22 UMTS [155][156] Netherlands KPN 2023-05-10 UMTS [157][158][159] Local shutdown commenced on 31 Mar 2022. Vodafone 2020-02-04 UMTS [160] New Zealand 2degrees 2025 Q4 (est.) UMTS [161] One 2025-12-31 (est.) UMTS [162][163][164] Local shutdown will commence by 31 Mar 2025. Spark 2025-12-31 (est.) UMTS [165][166] Local shutdown will commence "towards the end of 2025". Norway No Service Telia 2021-11-11 UMTS [167] Telenor 2021-01-31 UMTS [168] Oman Omantel 2024 Q3 (est.) UMTS [169][170] Pakistan No Service Jazz 2024-11-18 UMTS [171][172] Philippines Smart (PLDT) TBD UMTS [173] Globe TBD UMTS [174] Shutdown commenced in Oct 2020. Poland T-Mobile 2023-04 (est.) UMTS [175][176][177] Shutdown commenced in Apr 2023. Orange 2025-12-31 (est.) UMTS [53][178][179] Local shutdown commenced on 26 Sep 2023. Portugal MEO 2024-01-31 UMTS [180] Local shutdown commenced on 4 Sep 2023. Vodafone 2024-07 (est.) UMTS [181] NOS 2024-05 (est.) UMTS [182] Shutdown commenced in May 2024. Romania Digi 2023-08-29 UMTS [183] Orange 2025-12-31 (est.) UMTS [53] Telekom 2023-03-31 UMTS [184] Vodafone 2025-07-01 (est.) UMTS [185] Russia Beeline 2025 (est.) UMTS [186] Shutdown commenced in Moscow in Feb 2023. MTS 2025 (est.) UMTS [187] Shutdowns commenced in Saint-Petersburg in Oct 2024. Saudi Arabia stc 2022-12-31 UMTS [188] Singapore No Service M1 2024-08-01 UMTS [189][190] Singtel 2024-11-01 UMTS [189][190] StarHub 2024-11-01 UMTS [189][190] Slovakia O2 TBD UMTS [191] Local shutdown commences in Jan 2024. Orange 2024-02-22 UMTS [53][192][193] Telekom 2023-11-23 UMTS [194][195] Local shutdown commenced on 3 Oct 2023. Slovenia Telekom Slovenije 2022-09-30 UMTS [196] A1 Slovenija 2023-06-30 UMTS [197] South Africa 2025-03 (est.) [198][199] Per government statement South Korea KT 2012-03-19 CDMA2000 [200][201][202] CDMA2000 was also referred to as "2G" in South Korea, besides cdmaOne (IS-95).[203]CDMA2000 1X, 1xEV-DO Rel. 0KT also operates an UMTS "3G" network. LG U+ 2021-06-30 CDMA2000 [204][205][200][206] CDMA2000 1X, 1xEV-DO Rev. A, EV-DO Rev. B SK Telecom 2020-07-27 CDMA2000 [207][202][200][208] CDMA2000 was also referred to as "2G" in South Korea, besides cdmaOne (IS-95).[203]CDMA2000 1X, 1xEV-DO Rel. 0SKT also operates an UMTS "3G" network. Spain Movistar 2025 (est.) UMTS Orange 2025-12-31 (est.) UMTS [53] Vodafone España 2024-10-29 (est.) UMTS [209][210] Sri Lanka Airtel 2022-06-12 UMTS [211] Dialog Axiata TBD UMTS [212] Sweden Telenor 2025-12 (est.) UMTS [213] Telia 2025 (est.) UMTS [214] Three 2025-12-01 (est.) UMTS [215][216] Local shutdown for 2100 MHz commenced in late 2021. Switzerland Sunrise 2025-06 (est.) UMTS [217] Swisscom 2025-12-01 (est.) UMTS [218] Taiwan No Service Asia Pacific Telecom 2017-12-31 CDMA2000 [219][220] CDMA2000 1X, 1xEV-DO Rev. A Chunghwa Telecom 2018-12-31 (Data)2024-06-30 (Voice) UMTS [221][222][223] Far EasTone 2018-12-31 (Data)2024-06-30 (Voice) UMTS [221][222][223] Taiwan Mobile 2018-12-31 (Data)2024-06-30 (Voice) UMTS [221][222][223] Taiwan Star 2018-12-31 (Data)2024-06-30 (Voice) UMTS [221][222][223] United Kingdom EE 2024-02-25 UMTS [224][225][226][227] Three 2024-12-31 UMTS [228] O2 2025-12-31 (est.) UMTS [229][230] Local shutdown commenced in Apr 2025. Vodafone 2024-02-28 UMTS [231][232][233][234] Local shutdown commenced in Jun 2023. United States Puerto Rico US Virgin Islands No Service Appalachian Wireless 2023-01-03 CDMA2000 [235][236][237] CDMA2000 1X, 1xEV-DO Rev. A AT&T 2022-02-22 UMTS [238][239] Cellcom 2023-03-31 CDMA2000 [240] Cellular One of North East Arizona 2023-05-04 UMTS [241] Commnet Wireless (Choice) 2022-12-31 CDMA2000 [242] Liberty 2022-02-22 UMTS [243] Silver Star 2022-12-30 CDMA2000 [244][245] CDMA2000 1X & 1xEV-DO Rev. A Strata Networks 2022-12-31 CDMA2000 [246] T-Mobile 2022-07-01 UMTS [247][248][249][250] T-Mobile (Sprint) 2022-05-31 CDMA2000 [251][247][248][249][252][253] CDMA2000 1X, 1X Adv. (Rev.E), 1xEV-DO Rel. 0, 1xEV-DO Rev. AShutdown commenced on 31 Mar 2022. UScellular 2024-01-14 CDMA2000 [254][255][256] CDMA2000 1X1xEV-DO (Rel. 0 & Rev. A) shutdown commenced in 2021. Verizon 2022-12-31 CDMA2000 [257][258][259] CDMA2000 1X, 1xEV-DO Rel. 0, 1xEV-DO Rev. A Vietnam 2028-09 (est.) 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The participating associations were ARIB/TTC (Japan), China Communications Standards Association, Telecommunications Industry Association (North America) and Telecommunications Technology Association (South Korea). The agreement was established in December 1998. Ultra Mobile Broadband (UMB) was a 3GPP2 project to develop a fourth-generation successor to CDMA2000. In November 2008, Qualcomm, UMB's lead sponsor, announced it was ending development of the technology, favoring LTE instead.[1] 3GPP2 should not be confused with 3GPP; 3GPP is the standard body behind the Universal Mobile Telecommunications System (UMTS) that is the 3G upgrade to GSM networks, while 3GPP2 was the standard body behind the competing 3G standard CDMA2000 that is the 3G upgrade to cdmaOne networks that was used mostly in the United States (and to some extent also in Japan, China, Canada, South Korea and India). GSM/UMTS were the most widespread 2G/3G wireless standards worldwide. Most countries used only the GSM family. A few countries, including China, the United States, Canada, Ukraine, Trinidad and Tobago, India, South Korea and Japan, used both standards. 3GPP2 had its last activity in 2013,[2] and the group has been dormant ever since. The 3GPP2 website was taken offline in 2023, primarily due to CDMA carriers deploying 3GPP's LTE instead of UMB the decade prior and later shutting down CDMA networks making the 3GPP2 redundant and unneeded. However, as of 2024 the 3GPP2 website has since come back online. ^ Qualcomm halts UMB project, Reuters, 13 November 2008 ^ "3GPP2 Technology Webinar". 3GPP2. 3GPP2 Official Web site About 3GPP2 TIA – U.S. 3GPP2 Standards Developer This article about wireless technology is a stub. You can help Wikipedia by expanding it.vte Retrieved from " 7Mobile telecommunications standards body 3rd Generation Partnership ProjectAbbreviation3GPPFormation1998; 27 years ago (1998)TypeStandards organizationRegion served WorldwideWebsitewww.3gpp.org The 3rd Generation Partnership Project (3GPP) is an umbrella term for a number of standards organizations which develop protocols for mobile telecommunications. Its best known work is the development and maintenance of:[1] GSM and related 2G and 2.5G standards, including GPRS and EDGE UMTS and related 3G standards, including HSPA and HSPA+ LTE and related 4G standards, including LTE Advanced and LTE Advanced Pro 5G NR and related 5G standards, including 5G-Advanced An evolved IP Multimedia Subsystem (IMS) developed in an access independent manner 3GPP is a consortium with seven national or regional telecommunication standards organizations as primary members ("organizational partners") and a variety of other organizations as associate members ("market representation partners"). The 3GPP organizes its work into three different streams: Radio Access Networks, Services and Systems Aspects, and Core Network and Terminals.[2] The project was established in December 1998 with the goal of developing a specification for a 3G mobile phone system based on the 2G GSM system, within the scope of the International Telecommunication Union's International Mobile Telecommunications-2000, hence the name 3GPP.[3] It should not be confused with 3rd Generation Partnership Project 2 (3GPP2), which developed a competing 3G system, CDMA2000.[4] The 3GPP administrative support team (known as the "Mobile Competence Centre") is located at the European Telecommunications Standards Institute headquarters in the Sophia Antipolis technology park in France.[5] The seven 3GPP Organizational Partners are from Asia, Europe and North America. Their aim is to determine the general policy and strategy of 3GPP and perform the following tasks: The approval and maintenance of the 3GPP scope; The maintenance of the Partnership Project Description; Take the decision to create or cease a Technical Specification Groups, and approve their scope and terms of reference; The approval of Organizational Partner funding requirements; The allocation of human and financial resources provided by the Organizational Partners to the Project Co-ordination Group; Act as a body of appeal on procedural matters referred to them. Together with the Market Representation Partners (MRPs) perform the following tasks: The maintenance of the Partnership Project Agreement; The approval of applications for 3GPP partnership; Take the decision against a possible dissolution of 3GPP. The Organizational Partners are:[6] Organizational Partners Organization Country/region Website Association of Radio Industries and Businesses (ARIB) Japan ARIB Alliance for Telecommunications Industry Solutions (ATIS) USA ATIS China Communications Standards Association (CCSA) China CCSA European Telecommunications Standards Institute (ETSI) Europe ETSI Telecommunications Standards Development Society (TSDSI) India TSDSI Telecommunications Technology Association (TTA) South Korea TTA Telecommunication Technology Committee (TTC) Japan TTC The 3GPP Organizational Partners can invite a Market Representation Partner to take part in 3GPP, which: Has the ability to offer market advice to 3GPP and to bring into 3GPP a consensus view of market requirements (e.g., services, features and functionality) falling within the 3GPP scope; Does not have the capability and authority to define, publish and set standards within the 3GPP scope, nationally or regionally; Has committed itself to all or part of the 3GPP scope; Has signed the Partnership Project Agreement. As of January 2025[update], the Market Representation Partners are:[6] Market Representation Partners Organization Website 5G-ACIA 5G Automotive Association 5G Americas Deterministic Networking Alliance (5GDNA) 6G Smart Network and Services Industry Association (6G-IA) 5G Slicing Association (5GSA) 5G Media Action Group (5G-MAG) Automotive Edge Computing Consortium (AECC) Broadband India Forum Cellular Operators Association of India (COAI) China Society of Automotive Engineers (CSAE) CTIA Global Satellite Operators Association (GSOA) Global Certification Forum (GCF) Global mobile Suppliers Association (GSA) GSMA IPV6 Forum Next Generation Mobile Networks (NGMN) Public Safety Communication Europe (PSCE) Forum Small Cell Forum TCCA TD Industry Alliance Wireless Broadband Alliance 3GPP standards are structured as Releases. Discussion of 3GPP thus frequently refers to the functionality in one release or another. Version[7] Released[8] Info Phase 1 1992 GSM Features Phase 2 1995 GSM Features, EFR Codec, Release 96 1997 Q1 GSM Features, 14.4 kbit/s User Data Rate, Release 97 1998 Q1 GSM Features, GPRS Release 98 1999 Q1 GSM Features, AMR codec, EDGE, GPRS for PCS1900 Release 99 2000 Q1 Specified the first UMTS 3G networks, incorporating a CDMA air interface[9] Release 4 2001 Q2 Originally called the Release 2000 – added features including an all-IP Core Network[10] Release 5 2002 Q1 Introduced IMS and HSDPA[11] Release 6 2004 Q4 Integrated operation with Wireless LAN networks and adds HSUPA, MBMS, enhancements to IMS such as Push to Talk over Cellular (PoC), GAN[12] Release 7 2007 Q4 Focuses on decreasing latency, improvements to QoS and real-time applications such as VoIP.[13] This specification also focus on HSPA+ (High Speed Packet Access Evolution), SIM high-speed protocol and contactless front-end interface (Near Field Communication enabling operators to deliver contactless services like Mobile Payments), EDGE Evolution. Release 8 2008 Q4 First LTE release. All-IP Network (SAE). New OFDMA, FDE and MIMO based radio interface, not backwards compatible with previous CDMA interfaces. Dual-Cell HSDPA. UMTS HNB. Release 9 2009 Q4 SAES Enhancements, WiMAX and LTE/UMTS Interoperability. Dual-Cell HSDPA with MIMO, Dual-Cell HSUPA. LTE HeNB. Evolved multimedia broadcast and multicast service (eMBMS). Release 10 2011 Q1 LTE Advanced fulfilling IMT Advanced 4G requirements. Backwards compatible with release 8 (LTE). Multi-Cell HSDPA (4 carriers). Release 11 2012 Q3 Advanced IP Interconnection of Services. Service layer interconnection between national operators/carriers as well as third-party application providers. Heterogeneous networks (HetNet) improvements, Coordinated Multi-Point operation (CoMP). In-device Co-existence (IDC). Release 12 2015 Q1 Enhanced Small Cells (higher order modulation, dual connectivity, cell discovery, self configuration), Carrier aggregation (2 uplink carriers, 3 downlink carriers, FDD/TDD carrier aggregation), MIMO (3D channel modeling, elevation beamforming, massive MIMO), New and Enhanced Services (cost and range of MTC, D2D communication, eMBMS enhancements)[14] Release 13 2016 Q1 LTE-Advanced Pro. LTE in unlicensed, LTE enhancements for Machine-Type Communication. Elevation Beamforming / Full-Dimension MIMO, Indoor positioning.[15] Release 14 2017 Q2 Energy Efficiency, Location Services (LCS), Mission Critical Data over LTE, Mission Critical Video over LTE, Flexible Mobile Service Steering (FMSS), Multimedia Broadcast Supplement for Public Warning System (MBSP), enhancement for TV services over eMBMS, massive Internet of Things, Cell Broadcast Service (CBS)[16] Release 15 2018 Q2 First 5G NR ("New Radio") release. Support for 5G Vehicle-to-x service, IP Multimedia Core Network Subsystem (IMS), Future Railway Mobile Communication System[17] Release 16 2020 Q3 The 5G System – Phase 2: 5G enhancements, NR-based access to unlicensed spectrum (NR-U), Satellite access[18] Release 17 2022 Q1 TSG RAN: Several features that continue to be important for overall efficiency and performance of 5G NR: MIMO, Spectrum Sharing enhancements, UE Power Saving and Coverage Enhancements. RAN1 will also undertake the necessary study and specification work to enhance the physical layer to support frequency bands up to 71 GHz. TSG SA groups focused on further enhancements to the 5G system and enablers for new features and services: Enhanced support of: non-public networks, industrial Internet of Things, low complexity NR devices, edge computing in 5GC, access traffic steering, switch and splitting support, network automation for 5G, network slicing, advanced V2X service, multiple USIM support, proximity-based services in 5GS, 5G multicast broadcast services, Unmanned Aerial Systems (UAS), satellite access in 5G, 5GC location services, Multimedia Priority Service...[19] Release 18 2023 Q4 5G-Advanced. Introducing further machine-learning based techniques at different levels of the wireless network. Edge computing, Evolution of IMS Multimedia Telephony Service, Smart Energy and Infrastructure, Vehicle-Mounted Relays, Low Power High Accuracy Positioning for industrial IoT scenarios, Enhanced Access to and Support of Network slicing, Satellite backhaul in 5G...[20][21][19] Release 19 [22] 2025 Q4 5G-Advanced. Each release incorporates hundreds of individual Technical Specification and Technical Report documents, each of which may have been through many revisions. Current 3GPP standards incorporate the latest revision of the GSM standards. The documents are made available without charge on 3GPP's web site. The Technical Specifications cover not only the radio part ("Air Interface") and Core Network, but also billing information and speech coding down to source code level. Cryptographic aspects (such as authentication, confidentiality) are also specified. The 3GPP specification work is done in Technical Specification Groups (TSGs) and Working Groups (WGs).[23] There are three Technical Specifications Groups, each of which consists of multiple WGs: RAN (Radio Access Network): RAN specifies the UTRAN and the E-UTRAN. It is composed of six working groups. WG Shorthand Scope Specifications RAN WG1 RAN1 Radio Layer 1 (Physical layer) List of specs RAN WG2 RAN2 Radio Layer 2 and Radio Layer 3 Radio Resource Control List of specs RAN WG3 RAN3 UTRAN, E-UTRAN, NG-RAN architecture and related network interfaces List of specs RAN WG4 RAN4 Radio performance and protocol aspects List of specs RAN WG5 RAN5 Mobile terminal conformance testing List of specs SA (Service and System Aspects): SA specifies the service requirements and the overall architecture of the 3GPP system. It is also responsible for the coordination of the project. SA is composed of six working groups. WG Shorthand Scope Specifications SA WG1 SA1 Services List of specs SA WG2 SA2 Architecture List of specs SA WG3 SA3 Security List of specs SA WG4 SA4 Codec List of specs SA WG5 SA5 Management, Orchestration and Charging List of specs SA WG6 SA6 Application Enablement and Critical Communication Applications List of specs CT (Core Network and Terminals): CT specifies the core network and terminal parts of 3GPP. It includes the core network – terminal layer 3 protocols. It is composed of five working groups. WG Shorthand Scope Specifications CT WG1 CT1 User Equipment – Core Network protocols List of specs CT WG2 CT2 closed CT WG3 CT3 Interworking with external networks List of specs CT WG4 CT4 Core Network Protocols List of specs CT WG5 CT5 closed CT WG6 CT6 Smart Card Application Aspects List of specs GERAN (GSM/EDGE Radio Access Network): The closure of GERAN was announced in January 2016.[24] The specification work on legacy GSM/EDGE system was transferred to RAN WG, RAN6. RAN6 was closed in July 2020 (. The 3GPP structure also includes a Project Coordination Group, which is the highest decision-making body. Its missions include the management of overall timeframe and work progress. 3GPP standardization work is contribution-driven. Companies ("individual members") participate through their membership to a 3GPP Organizational Partner. As of December 2020, 3GPP is composed of 719 individual members.[25] Specification work is done at WG and at TSG level:[26] the 3GPP WGs hold several meetings a year. They prepare and discuss change requests against 3GPP specifications. A change request accepted at WG level is called "agreed". the 3GPP TSGs hold plenary meetings quarterly. The TSGs can "approve" the change requests that were agreed at WG level. Some specifications are under the direct responsibility of TSGs and therefore, change requests can also be handled at TSG level. The approved change requests are subsequently incorporated in 3GPP specifications. 3GPP follows a three-stage methodology as defined in ITU-T Recommendation I.130:[27] stage 1 specifications define the service requirements from the user point of view. stage 2 specifications define an architecture to support the service requirements. stage 3 specifications define an implementation of the architecture by specifying protocols in details. Test specifications are sometimes defined as stage 4, as they follow stage 3. Specifications are grouped into releases. A release consists of a set of internally consistent set of features and specifications. Timeframes are defined for each release by specifying freezing dates. Once a release is frozen, only essential corrections are allowed (i.e. addition and modifications of functions are forbidden). Freezing dates are defined for each stage. The 3GPP specifications are transposed into deliverables by the Organizational Partners. List of mobile phone generations Universal Mobile Telecommunications System (UMTS) 3GPP Long Term Evolution Evolution to 3G IP Multimedia Subsystem 3GP 3GPP2 – The 3GPP's counterpart in the CDMA2000 sphere. GSM services LoRaWAN Telecoms & Internet converged Services & Protocols for Advanced Networks (TISPAN) Open Mobile Alliance Service data adaptation protocol Service layer European Telecommunications Standards Institute ^ 3GPP Scope and Objectives, 31 August 2007 ^ "About 3GPP". 3GPP. Retrieved 10 March 2019. ^ "3GPP Background". 7 June 2000. Archived from the original on 6 July 2000. ^ "3rd Generation Partnership Project 2". Archived from the original on 23 January 2004. Retrieved 25 November 2012. ^ "Mobile Competence Centre". 3GPP. Retrieved 10 March 2019. ^ a b "Partners". 3GPP. Retrieved 1 January 2025. ^ Releases ^ "3GPP Specifications – Releases (and phases and stages)". Retrieved 16 September 2010. ^ Overview of 3GPP Release 99, Summary of all Release 99 Features. 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Retrieved 11 April 2011. ^ closure of GERAN ^ 3GPP membership ^ 3GPP TR 21.900 Technical Specification Group working methods ^ ITU-T Recommendation I.130 3GPP website 3GPP Standards List of Acronyms & Terminology 3GPP freely published, detailed technical specifications 3GPP releases descriptions ETSI GSM UMTS 3GPP Numbering Cross Reference TS/TR specification numbering Tool for visualizing multiple inter-related 3gpp standards Tool for visualizing, decoding, encoding network protocol messages defined by 3gpp LTE-3GPP.info: online 3GPP messages decoder fully supporting Rel.15 Retrieved from " 8Multimedia file format families 3GPFilename extension .3gp, .3gppInternet media type video/3gpp, audio/3gppUniform Type Identifier (UTI)public.3gppDeveloped by3GPPInitial release4 April 2003; 22 years ago (2003-04-04)[1]Latest release17.0.0[1]7 April 2022; 3 years ago (2022-04-07) Type of formatContainer formatContainer foraudio, video, textExtended fromMPEG-4 Part 12Open format?YesFree format?No 3G2Filename extension .3g2, .3gp2, .3gpp2Internet media type video/3gpp2, audio/3gpp2Uniform Type Identifier (UTI)public.3gpp2Developed by3GPP2Initial releaseJanuary 2004; 21 years ago (2004-01)[2]Latest releaseC.S0050-B v1.0[2]September 2024; 8 months ago (2024-09) Type of formatContainer formatContainer foraudio, video, textExtended fromMPEG-4 Part 12Open format?YesFree format?yes 3GP (3GPP file format) is a digital multimedia container format defined by the Third Generation Partnership Project (3GPP) for 3G UMTS multimedia services, largely based on MPEG-4 Part 12. 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View (previous 50 | next 50) (20 | 50 | 100 | 250 | 500)Au file format (links | edit) Data compression (links | edit) GIF (links | edit) H.263 (links | edit) ITU-T (links | edit) JPEG (links | edit) JPEG Network Graphics (links | edit) MP3 (links | edit) Moving Picture Experts Group (links | edit) MPEG-1 (links | edit) MPEG-2 (links | edit) MPEG-4 (links | edit) Multiple-image Network Graphics (links | edit) Ogg (links | edit) PNG (links | edit) QuickTime (links | edit) Run-length encoding (links | edit) Vorbis (links | edit) WAV (links | edit) Windows Media Audio (links | edit) Audio Video Interleave (links | edit) M-law algorithm (links | edit) ATRAC (links | edit) Image compression (links | edit) RealMedia (links | edit) Video codec (links | edit) RealAudio (links | edit) Discrete cosine transform (links | edit) JPEG 2000 (links | edit) Shorten (codec) (links | edit) Interchange File Format (links | edit) Audio Interchange File Format (links | edit) DivX (links | edit) FLAC (links | edit) Dolby Digital (links | edit) G.723.1 (links | edit) G.711 (links | edit) Resource Interchange File Format (links | edit) TIFF (links | edit) Material Exchange Format (links | edit) MPEG-1 Audio Layer II (links | edit) Theora (links | edit) Dirac (video compression format) (links | edit) Monkey's Audio (links | edit) Motion JPEG (links | edit) MPEG-7 (links | edit) MPEG-21 (links | edit) Xvid (links | edit) FFmpeg (links | edit) Advanced Audio Coding (links | edit) View (previous 50 | next 50) (20 | 50 | 100 | 250 | 500) Retrieved from " WhatLinksHere/3GP_and_3G2"

Polygraph tests, often regarded as the ultimate tool for assessing truthfulness, raise questions about their diagnostic value and reliability. Clients—whether businesses, families, or even legal institutions—frequently inquire about the accuracy of these tests. Terms like "95% accuracy" are commonly cited, but understanding the nuances of diagnostic value versus error probability is essential. Understanding Diagnostic Value in Polygraph Tests The diagnostic value of a polygraph test refers to its accuracy and reliability. This depends on several factors: Test Type: Single-issue tests (e.g., You-Phase or Utah ZCT) versus multi-issue tests (e.g., Utah MGQT or USAF MGQT v.2). Number of Relevant Questions: More questions can affect diagnostic precision. Scoring Methodology: Systems like ESS (Empirical Scoring System) or Utah scoring impact the results. Single-issue tests generally have higher diagnostic value. For instance: You-Phase (Bi-Zone): 90.4% diagnostic value (ESS). Utah ZCT: 92.1% (ESS) or 93% (Utah scoring). By comparison, multi-issue tests like Utah MGQT, despite allowing up to four critical questions, achieve a diagnostic value of 87.5%. This makes them unsuitable for evidentiary purposes but popular for private cases where multiple questions are prioritized. What Is Error Probability? Error probability, distinct from diagnostic value, refers to the likelihood of an incorrect result. It is calculated by analyzing physiological responses across multiple test series (3–5 repetitions). Each question (spot) is evaluated individually through channels such as: In single-issue tests, scores for all critical questions (e.g., R1, R2, R3 in Utah ZCT) are summed across series. A conclusive score indicates whether the subject's responses align with truthful or deceptive patterns. Occasionally, responses are inconclusive, though this is rare. In multi-issue tests, the lowest score among all questions determines the final evaluation. For example: R4: +2 R5: +8 R7: +1 R8: +4 Here, the evaluation relies on R7's score (+1), which has the highest error probability. If the calculated error probability is 2.4%, the test result is 97.6% reliable. This is often misinterpreted as the test's diagnostic value, underscoring the need to distinguish between the two concepts. Real-World Applications For evidentiary purposes, organizations like the American Polygraph Association (APA) and British Polygraph Society recommend tests with diagnostic values of 90% or higher. For private or business cases, multi-issue tests are more flexible, balancing reliability with practicality. The Role of Neutral Environments Test environments also influence results. For example, a recent private examination conducted in Katowice emphasized neutrality to ensure psychological comfort for both the subject and the polygrapher. While unconventional, such accommodations can enhance the reliability of results. Conclusion Understanding the diagnostic value and error probability of polygraph tests is key to interpreting their results. While single-issue tests provide higher accuracy, multi-issue tests offer flexibility for private cases. Clients must consider these factors to make informed decisions about the use of polygraph examinations.