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Palmer/MesHD002684 This article is part of a series on Alternative medicine General information Alternative medicine History Terminology Alternative veterinary medicine Quackery (health fraud) Rise of modern medicine Pseudoscience Antiscientific Skepticism Skeptical movement Therapeutic nihilism Fringe medicine and science Acupressure Acupuncture Alkaline diet Anthroposophic medicine Apitherapy Applied kinesiology Aromatherapy Association for Research and Enlightenment Auriculotherapy Bates method Black salve Bodywork Bonesetter Bowen technique Breathwork Camel urine Fake COVID-19 treatments Cancer treatments Charcoal cleanse Chiropractic Chiropractic treatment techniques Vertebral subluxation Christian Science Chromotherapy Colon cleansing Coffee enema Colorpuncture Colloidal silver Craniosacral therapy Crystal healing Cupping therapy Dental amalgam controversy Foot detox Dry needling Ear candling Energy medicine Corrective therapy Esoteric medicine Therapeutic touch Estrogen dominance Fabian Antiviral Injection Method Functional medicine Hair analysis Herbal medicine Holistic bracelet Homeopathy Bach flower remedies Biological terrain assessment Hypnotherapy Irridology Ionized jewelry Jelly Juice Lighting Process Lymphotherapy Medical intuitive Mesmerism Magnet therapy Manual therapy Megavitamin therapy Mind-body intervention MMS Myofascial release NAET Naturopathy Oil pulling Oregons Orthomolecular medicine Orthopathy Osteopathy Ozene therapy Parapsychology Phenology Postural Integration Psychiatric Psychodermatology Quantum healing Radionics Rapid prompting method RBOP Reiki Reflexology Rolling Scientific racism Theta Healing Field Therapy Urography Vaginal steaming Vision therapy Vitalism Vegetotherapy Young blood transfusion Zero balancing Conspiracy theories (list) Big Pharma conspiracy theory HIV/AIDS denialism OPV AIDS hypothesis Anti-vaccinationism in chiropractic Vaccines and autism MMR vaccine and autism Water fluoridation controversy GMO conspiracy theories COVID-19 misinformation Classifications Alternative medical systems Mind-body intervention Biologically-based therapy Manipulative methods Energy therapy Traditional medicine African Muti Southern Africa Ayurveda Doshas MVAH Balneotherapy Brazilian Bush medicine Cambodian Chinese Blood stasis Chinese herbology Dit da Gua sha Gil plate trade Meridian Moxibustion Pressure point Qi San Jiao Tui na Zang-fu Chuamash Curandero Faith healing Ilion Iranian Jamu Kambo Japanese Korean Mien Shiam Shanxi Sichuan Sri Lankan Thai massage Tibetan Unani Vietnamese Diagnoses Adrenal fatigue Aerotoxic syndrome Candida hypersensitivity Chronic Lyme disease Electromagnetic hypersensitivity Heavy legs Leaky gut syndrome Multiple chemical sensitivity Vertebral subluxation Chiropactic is a form of alternative medicine [1] concerned with the diagnosis, treatment and prevention of mechanical disorders of the musculoskeletal system, especially of the spine.[2] It has esoteric origins[3] and is based on several pseudoscientific ideas.[4] Many chiropractors, especially those in the field's early history, have proposed that mechanical disorders of the joints, especially of the spine, affect general health,[2] and that regular manipulation of the spine (spinal adjustment) improves general health. The main chiropractic treatment technique involves manual therapy, especially manipulation of the spine, other joints, and soft tissues, but may also include exercises and health and lifestyle counseling.[5] A chiropractor may have a Doctor of Chiropractic (D.C.) degree and be referred to as "doctor" but is not a Doctor of Medicine (M.D.)(6)[7] While many chiropractors view themselves as primary care providers,[8][9] chiropractic clinical training does not meet the requirements to be such a provider.[2] Systematic reviews of controlled clinical studies of treatments used by chiropractors have found no evidence that chiropractic manipulation is effective, with the possible exception of treatment for back pain.[8] A 2011 critical evaluation of 45 systematic reviews found that spinal manipulation was ineffective at treating any condition.[10] Spinal manipulation may be cost-effective for sub-acute or chronic low back pain, but the results for acute low back pain were insufficient.[11] No compelling evidence exists to indicate that maintenance chiropractic care adequately prevents symptoms or diseases.[12] There is not sufficient data to establish the safety of chiropractic manipulations.[13] It is frequently associated with mild to moderate adverse effects, with serious or fatal complications in rare cases.[14] There is controversy regarding the degree of risk of vertebral artery dissection, which can lead to stroke and death from cervical manipulation.[15] Several deaths have been associated with this technique[14] and it has been suggested that the relationship is causative.[16][17] A claim which is disputed by many chiropractors.[17] Chiropractic is well established in the United States, Canada, and Australia.[18] It overlaps with other manual-therapy professions such as osteopathy and physical therapy.[19] Most who seek chiropractic care do so for low back pain.[20] Back and neck pain are considered the specialties of chiropractic, but many chiropractors treat ailments other than musculoskeletal issues.[8] Chiropractic has two main groups: "straights", now the minority, emphasize vitalism, "Innate Intelligence", and consider vertebral subluxations to be the cause of all disease; and "mixers", the majority, are more open to mainstream views and conventional medical techniques, such as exercise, massage, and ice therapy.[21] D. D. Palmer founded chiropractic in the 1890s,[22] after saying he received it from "the other world";[23]

Palmer maintained that the tenets of chiropractic were passed along to him by a doctor who had died 50 years previously.[24] His son B. J. Palmer helped to expand chiropractic in the early 20th century.[22] Throughout its history, chiropractic has been controversial.[25][26] Its foundation is at odds with evidence-based medicine, and has been sustained by pseudoscientific ideas such as vertebral subluxation and innate intelligence.[27] Despite the overwhelming evidence that vaccination is an effective public health intervention, among chiropractors there are significant disagreements over the subject,[28] which has led to negative impacts on both public vaccination and mainstream acceptance of chiropractic.[29] The American Medical Association called chiropractic an "unscientific cult" in 1966[30] and boycotted it until losing an antitrust case in 1987.[9] Chiropractors have had a strong political base and sustained demand for services. In the last decades of the twentieth century, it gained more legitimacy and greater acceptance among conventional physicians and health plans in the United States.[9] During the COVID-19 pandemic, chiropractic professional associations advised chiropractors to adhere to CDC, WHO, and local health department guidance.[31][32] Despite these recommendations, a small but vocal and influential number of chiropractors spread anti-vaccine disinformation.[33] Conceptual basis Philosophy Chiropractic is generally categorized as complementary and alternative medicine (CAM),[1] which focuses on manipulation of the musculoskeletal system, especially the spine.[2] Its founder, D. D. Palmer, called it "a science of healing without drugs".[8] Chiropractic's origins lie in the folk medicine of bone-setting,[8] and as it evolved it incorporated vitalism, spiritual inspiration and rationalism.[34] Its early philosophy was based on deduction from irrefutable doctrine, which helped distinguish chiropractic from medicine, provided it with legal and political defenses against claims of practicing medicine without a license, and allowed chiropractors to establish themselves as an autonomous profession.[34] This "straight" philosophy, taught to generations of chiropractors, rejects the inferential reasoning of the scientific method,[34] and relies on deductions from vitalistic first principles rather than on the materialism of science.[35] However, most practitioners tend to incorporate scientific research into chiropractic,[34] and most practitioners are "mixers" who attempt to combine the materialistic reductionism of science with the metaphysics of their predecessors and with the holistic paradigm of wellness.[35] A 2008 commentary proposed that chiropractic actively divorce itself from the straight philosophy as part of a campaign to eliminate untestable dogma and engage in critical thinking and evidence-based research.[36] Two chiropractic belief system constructs The testable principle The untestable metaphor Chiropractic adjustment 1 Restoration of structural integrity 1 Improvement of health status Universal intelligence 1 Innate intelligence 1 Body physiology Materialistic: Operational definitions possibly extend to scientific inquiry Origin of life in chiropractic Cannot be proven or disproven Taken from Mootz & Phillips 1997[35] Although a wide diversity of ideas exist among chiropractors,[34] they share the belief that the spine and health are related in a fundamental way, and that this relationship is mediated through the nervous system.[37] Some chiropractors claim spinal manipulation can have an effect on a variety of ailments such as irritable bowel syndrome and asthma.[38] Chiropractic philosophy includes the following perspectives:[35] Holism assumes that health is affected by everything in an individual's environment; some sources also include a spiritual or existential dimension.[39] In contrast, reductionism in chiropractic reduces causes and cures of health problems to a single factor, vertebral subluxation.[38] Homeostasis emphasizes the body's inherent self-healing abilities. Chiropractic's early notion of innate intelligence can be thought of as a metaphor for homeostasis.[34] A large number of chiropractors feel that if they do not separate themselves from the traditional vitalistic concept of innate intelligence, chiropractic will continue to be seen as a fringe practice.[31] A variant of chiropractic called naprapathy originated in Chicago during the twentieth century.[40][41] It holds that normal soft tissue can reduce "interference" in the body and thus improve health.[41] Straights and mixers Range of belief perspectives in chiropractic Perspective attribute Potential belief endpoints Scope of practice: narrow ("straight") — broad ("mixer") Diagnostic approach: intuitive → materialistic Chiropractic orientation to health and disease Professional integration: traditional and alternative medicine, including nutritional supplements, acupuncture, homeopathy, herbal remedies, and biofeedback.[21] Although mixers are the majority group, many of them retain belief in vertebral subluxation as shown in a 2003 survey of 1,100 North American chiropractors, which found that 88 percent wanted to retain the term "vertebral subluxation complex", and that when asked to estimate the percent of disorders of internal organs that subluxation significantly contributed to, the mean response was 62 percent.[43] A 2008 survey of 6,000 American chiropractors demonstrated that most chiropractors generally believed that the majority of their clinical approach for addressing musculoskeletal/biomechanical disorders such as back pain was based on subluxation.[44] Chiropractors often offer conventional therapies such as physical therapy and lifestyle counseling, and it may for the lay person be difficult to distinguish the unscientific from the scientific.[45] Vertebral subluxation Main article: Vertebral subluxation Not to be confused with subluxation, the medical condition. In science-based medicine, the term "subluxation" refers to an incomplete or partial dislocation of a joint, from the Latin *luxare* for "dislocate".[46][47] While medical doctors use the term exclusively to refer to physical dislocations, Chiropractic founder D. D. Palmer imbued the word subluxation with a metaphysical and philosophical meaning drawn from pseudoscientific traditions such as Vitalism.[48] He qualified this by noting that knowledge of innate intelligence was not essential to the competent practice of chiropractic.[48] This concept was later expanded upon by his son, B. J. Palmer, and was instrumental in providing the legal basis of differentiating chiropractic from conventional medicine. In 1910, D. D. Palmer theorized that the nervous system controlled health: "Physiologists divide nerve-fibers, which form the nerves, into two classes, afferent and efferent. Impressions are made on the peripheral afferent fiber-endings these create sensations that are transmitted to the center of the nervous system. Efferent nerve-fibers carry impulses out from the center to their endings. Most of these go to muscles and are therefore called motor impulses; some are secretory and enter glands; a portion are inhibitory, their function being to restrain secretion. Thus, nerves carry impulses outward and sensations inward. The activity of these nerves, or rather their fibers, may become excited or allayed by impingement, the result being a modification of functionality — too much or not enough action — which is disease".[50] Chiropractors use x-ray radiography to examine the bone structure of a patient. Vertebral subluxation, a core concept of traditional chiropractic, remains unsubstantiated and largely untested, and a debate about whether to keep it in the chiropractic paradigm has been ongoing for decades.[51] In general, critics of traditional subluxation-based chiropractic (including chiropractors) are skeptical of its clinical value, dogmatic beliefs and metaphysical approach. While straight chiropractic still retains the traditional vitalistic construct espoused by the founders, evidence-based chiropractic suggests that a mechanistic view will allow chiropractic care to become integrated into the wider health care community.[51] This is still a continuing source of debate within the chiropractic profession as well, with some schools of chiropractic still teaching the traditional/straight-subluxation-based chiropractic, while others have moved towards an evidence-based chiropractic that rejects metaphysical foundations and limits itself to primarily neuromusculoskeletal conditions.[52][53] In 2005, the chiropractic subluxation was defined by the World Health Organization as "a lesion or dysfunction in a joint or motion segment in which alignment, movement integrity and/or physiological function are altered, although contact between joint surfaces remains intact".[54] It is essentially a functional entity, which may influence biomechanical and neural integrity.[54] This differs from the medical definition of subluxation as a significant structural displacement, which can be seen with static imaging techniques such as X-rays.[54] The use of X-ray imaging in the case of vertebral subluxation exposes patients to harmful ionizing radiation for no evidentially supported reason.[55][56] The 2008 book Trick or Treatment states "X-rays can reveal neither the subluxations nor the innate intelligence associated with chiropractic philosophy, because they do not exist".[57] Attorney David Chapman-Smith, Secretary-General of the World Federation of Chiropractic, has stated that "Medical critics have asked how there can be a subluxation if it cannot be seen on X-ray. The answer is that the chiropractic subluxation is essentially a functional entity, not structural, and is therefore no more visible on static X-ray than a limp or headache or any other functional problem".[58] The General Chiropractic Council, the statutory regulatory body for chiropractors in the United Kingdom, states that the chiropractic vertebral subluxation complex "is not supported by any clinical research evidence that would allow claims to be made that it is the cause of disease".[59] As of 2014, the National Board of Chiropractic Examiners states "The specific focus of chiropractic practice is known as the chiropractic subluxation or joint dysfunction. A subluxation is a health concern that manifests in the skeletal joints, and, through complex anatomical and physiological relationships, affects the nervous system and may lead to reduced function, disability or illness".[60][27] Pseudoscience versus spinal manipulation therapy Main articles: Spinal adjustment and Spinal manipulation While some chiropractors limit their practice to short-term treatment of musculoskeletal conditions, many falsely claim to be able treat a myriad of other conditions.[61] Some dissident patients from seeking medical care, others have pretended to be qualified to act as a family doctor.[61] Quackwatch, an alternative medicine watchdog, cautions against seeing chiropractors who [61][63] Treat young children Discourage immunization Pretend to be a family doctor Take full spine X-rays Promote unproven dietary supplements Are antagonists to scientific medicine Claim to treat non-musculoskeletal problems Writing for the Skeptical Inquirer, one physician cautioned against seeing even chiropractors who solely claim to treat musculoskeletal conditions: "I think Spinal Manipulation Therapy (SMT) is a reasonable option for patients to try ... But I could not in good conscience refer a patient to a chiropractor... When chiropractic is effective, what is effective is not 'chiropractic': it's SMT. SMT is also offered by physical therapists, DOs, and others. These are science-based providers... If I thought a patient might benefit from manipulation, I would rather refer him or her to a science-based provider.[61] Scope of practice A treatment table at a chiropractic office Chiropractors emphasize the conservative management of the neuromusculoskeletal system without the use of medicines or surgery,[54] with special emphasis on the spine.[2] Back and neck pain are the specialties of chiropractic but many chiropractors treat ailments other than musculoskeletal issues.[8] There is a range of opinions among chiropractors: some believed that treatment should be confined to the spine, or back and neck pain; others disagreed.[64] For example, while one 2009 survey of American chiropractors had found that 73% classified themselves as "back pain/musculoskeletal specialists", the label "back and neck pain specialists" was regarded by 47% of them as a least desirable description in a 2005 international survey.[64] Chiropractic combines aspects from mainstream and alternative medicine, and there is no agreement about how to define the profession: although chiropractors have many attributes of primary care providers, chiropractic has more attributes of a medical specialty like dentistry or podiatry.[65] It has been proposed that chiropractors specialize in nonsurgical spine care, instead of attempting to also treat other problems.[36][65] but the more expansive view of chiropractic is still widespread.[66] Mainstream health care and governmental organizations such as the World Health Organization consider chiropractic to be complementary and alternative medicine (CAM);[1] and a 2008 study reported that 31% of surveyed chiropractors categorized chiropractic as CAM, 27% as integrated medicine, and 12% as mainstream medicine.[67] Many chiropractors believe they are primary care providers,[8][9] including US[68] and UK chiropractors,[69] but the length, breadth, and depth of chiropractic clinical training do not support the requirements to be considered primary care providers,[2] so their role on primary care is limited and disputed.[2][9] Chiropractic overlaps with several other forms of manual therapy, including massage therapy, osteopathy, physical therapy, and sports medicine.[19][70] Chiropractic is autonomous from and competitive with mainstream medicine,[71] and osteopathy outside the US remains primarily a manual medical system;[72] physical therapists work alongside and cooperate with mainstream medicine, and osteopathic medicine in the U.S. has merged with the professional[73] Practitioners may distinguish their competing approaches through claims that, compared to other therapists, chiropractors heavily emphasize spinal manipulation, tend to use firmer manipulative techniques, and promote maintenance treatment; that osteopaths use a wider variety of treatment procedures; and that physical therapists emphasize pain and exercise.[19] Chiropractic diagnosis may involve a range of methods including spinal imaging, observational and tactile assessment, orthopedic and neurological evaluation.[54] A chiropractor may also refer a patient to an appropriate specialist or co-management health care provider.[65] Chiropractic patient management involves manipulation, mobilization, and soft tissue rehabilitative exercise, health promotion, electrical modalities, manipulation, and life advice.[65] A chiropractor's adjustment of a person's spine is a procedure of a diverse nature, and requires special licensing to perform medical procedures in a professional setting. Major surgery is performed by licensed physicians and dentists, and little is known about the safety of chiropractic care for certain medications.[74][75] In the US, their scope of practice varies by state, based on inconsistent views of chiropractic care, some states, such as Iowa, hardly allow treatment of "human ailments"; some, such as Delaware, use vague concepts such as "transition of nerve energy" to define scope of practice, others, such as New Jersey, specify a severely narrowed scope.[76] US states also differ over whether chiropractors may conduct laboratory tests or diagnostic procedures, dispense dietary supplements, or use other therapies such as homeopathy or acupuncture. In Oregon they can become certified to perform minor surgery and to deliver children via natural childbirth.[73] A 2003 survey of North American chiropractors found that a slight majority allowed them to write prescriptions for over-the-counter drugs.[43] A 2010 survey found strong evidence that suggests chiropractors limit their practice to short-term treatment of musculoskeletal conditions, many falsely claim to be able treat a myriad of other conditions.[61] Some dissident patients from seeking medical care, others have pretended to be qualified to act as a family doctor. Take full spine X-rays Promote unproven dietary supplements Are antagonists to scientific medicine Claim to treat non-musculoskeletal problems Writing for the Skeptical Inquirer, one physician cautioned against seeing even chiropractors who solely claim to treat musculoskeletal conditions: "I think Spinal Manipulation Therapy (SMT) is a reasonable option for patients to try ... 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Major surgery is performed by licensed physicians and dentists, and little is known about the safety of chiropractic care for certain medications.[74][75] In the US, their scope of practice varies by state, based on inconsistent views of chiropractic care, some states, such as Iowa,

amount of flexible, mobile-use spectrum the FCC had licensed to date.[53] In March 2018, European Union lawmakers agreed to open up the 3.6 and 26 GHz bands by 2020.[54] As of March 2019[update], there are reportedly 52 countries, territories, special administrative regions, disputed territories and dependencies that are currently considering 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.[55] In March 2019, the Global Mobile Suppliers Association released the industry's first database tracking worldwide 5G device launches.[56] In it, the GSA identified 23 vendors who have confirmed the availability of forthcoming 5G devices with 53 different devices including regional variants. There were seven announced 5G device form factors: (telephones (>12 devices), hotspots (x4), indoor and outdoor customer-premises equipment (x8), modules (x5), Snap-on dongles and adapters (x2), and USR terminals (x1). [57] By October 2019, the number of announced 5G devices had risen to 129, across 15 form factors, from 56 vendors.[58] In the 5G IoT chipset arena, as of April 2019 there were four commercial 5G modem chipsets and one vendor processor/platform, with more launches expected in the near future.[59] On March 6, 2020, the first-ever all-5G smartphone Samsung Galaxy S20 was released. According to Business Insider, the 5G feature was showcased as more expensive in comparison with 4G; the line up starts at US\$1,000, in comparison with Samsung Galaxy S10e which started at US\$750.[60] On March 19, HMD Global, the current maker of 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, with an initial Eurozone price of €599, is claimed to support all 5G bands from 600 MHz to 3.8 GHz.[61] Many phone manufacturers support 5G. The Apple iPhone 12 and later versions support 5G.[62][63] Google Pixel phones support it, since version 5a.[64] Technology News Radio frequency See also: 5G NR frequency bands The air-interface model, defined by 3GPP for 5G is known as New Radio (NR), and the specification is subdivided into two frequency bands, FR1 below 6 GHz and FR2 (24–54 GHz). Frequency range 1 (< 6 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 used for 5G in this range is 3.3–4.2 GHz. The Korean carriers use the n78 band at 3.5 GHz. Some parts use the term "multi-band" frequency to refer to higher part of this frequency range that was not used in previous generations of mobile communication. Frequency range 2 (24–54 GHz) The maximum channel bandwidth defined for FR2 is 50 MHz and the maximum is 400 MHz, with two-channel aggregation supported in 3GPP Release 15. The higher the frequency, the greater the ability to support higher data rates. Signals can travel shorter distances at higher frequencies, so more base stations are required for coverage in order to use higher frequency bands. Also, these higher frequency 5G signals cannot penetrate solid objects, such as cars, trees, and walls, 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.[65] Cell types Deployment Environment. Max. number of users Output power (mW) Max. distance from base station 5G NR FR2 Femtocells. Businesses, Home, 4-Businesses, 16–32 indoor, 10–100 outdoors, 200–1,000 tons of meters Pico cell. Public areas like shopping malls, airports, train stations, skyscrapers 64 to 128 indoors, 100–250 outdoors, 1,000–5,000 tons of meters Micro cell. Urban areas to fill coverage gaps 128 to 256 outdoors 5,000–10,000 few hundreds of meters Metro cell. Urban areas to provide additional capacity more than 250 outdoors, 10,000–20,000 hundreds of meters Wi-Fi (for comparison) Homes, businesses fewer than 50 indoors, 20–100 outdoors, 200–10,000 few tens of meters Massive MIMO See also: Multi-user MIMO MIMO 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. Massive MIMO (multiple-input and multiple-output) 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.[citation needed] Edge computing Main article: Multi-access edge computing Edge computing is delivered by computing servers closer to the ultimate user. It reduces latency, data traffic congestion[66][67] and can improve service availability.[68] Small cell. 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.[69][70][71][72] Beamforming Main article: Beamforming There are two kinds of beamforming: digital and analog. Digital beamforming involves sending the data across multiple streams (layers), while analog beamforming shaping the radio waves point to a specific direction. The analog BF technique combines the power from elements of the antenna array in such a way that 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.[citation needed] 5G uses both digital and analog beamforming to improve the system capacity.[citation needed] Convergence of Wi-Fi and cellular 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 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 could 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."Article - 5G | Solwise Ltd". Noma (non-orthogonal multiple access) NOMA (non-orthogonal multiple access) is a proposed multiple-access technique for future cellular systems via allocation of power.[citation needed] SDN/NFV 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.[73] In this context, network slicing has emerged as a key technology to efficiently embrace this new market model.[74] Channel coding 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.[75][76] Operation in unlicensed spectrum known as 5G NR-U, targeting 3GPP Release 16.[77] Qualcomm has made a similar proposal for LTE in unlicensed spectrum. Future evolution 5G-Advanced is a name for 3GPP release 18, which as of 2021[update] is under conceptual development.[78][79][80] Concerns about Chinese involvement in 5G wireless networks and Criticism of Huawei & Espionage and security concerns 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).[81] 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".[82][83] 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,[84] Arbor Networks,[85] and Voxility[87] 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.[88] This can raise the attack surface for these devices to a substantial scale, and the capacity for DDoS attacks, cryptjacking, and other cyberattacks could boost proportionally.[83] Due to fears of potential espionage of users of Chinese equipment, several countries (including the United States, Australia and the United Kingdom) as of 2019[89] have taken actions to restrict or eliminate the use of Chinese equipment in their respective 5G networks. Chinese vendors and the Chinese government have denied claims of espionage.[clarification needed] On 7 October 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.[90] Electromagnetic interference Weather forecasting Parts of this article (those related to Systems are turned on; is this happening?) need 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.[91] 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.[92][93] Interference to satellite operations impairs numerical weather prediction performance with substantially deleterious economic and public safety impacts in areas such as commercial aviation.[94][95] 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.[96] 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.[97] 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 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.[98] 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 its recommendation brings the "potential to significantly degrade the accuracy of data collected".[100] A representative of the American Meteorological Society (AMS) also warned of interference.[101] and the European Centre for Medium-Range Weather Forecasts (ECMWF), sternly warned, saying that society risks "history repeating itself" by ignoring atmospheric scientists' warnings (referencing global warming, monitoring of which could be imperiled).[102] 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.[103] Aviation 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[104] which lack protection from neighboring bands.[105] This is not as much of an issue in Europe, where 5G uses lower frequencies between 3.4 and 3.8 GHz.[106] Nonetheless, the DGAC in France has also expressed similar worries and recommended 5G phones be turned off or put in airplane mode during flights.[107] 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 also asked the cellular providers to hold off their new 5G service until 5G priority airports to minimize disruption to air traffic that could be caused by some planes being dislodged from landing by poor visibility.[108] After coming to an agreement with government officials on January 19, 2022, except for certain towers near 50 airports, AT&T and Verizon delayed 5G rollouts until further notice and agreed with the FAA required.[111] The FAA rushed to test and certify radar altimeters for interference so that airports could continue to use 5G. It had certified equipment at 45% of the U.S. fleet, or 7,900 towers, by January 20, 2021. At the same time, the FAA[112] stressed that the affected altimeters in the United States would avoid 5G signals at about 30% of flight (32,000) with the affected altimeters in Europe at about 10% of flight (3,200) would be canceled by the evening of January 18, 2021. Further information, C band (IEEE) Satellites A number of C-band satellite stations, which operate by receiving satellite signals at the radio frequency band of 3.3–3.6 GHz is expected to cause interference with Wi-Fi and satellite stations, which operate in unlicensed spectrum, as well as Wi-Fi 6e. However, interference could occur with the co-existence of different standards in the frequency band.[116] Overhype 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,[117] ability for 5G's mmWave signal to provide significant coverage,[118][119] overstatement what 5G can achieve or misattributing continuous technological improvement to "5G" [120] lack of new use case for carriers to profit from,[121] wrong focus on emphasizing direct benefits on individual consumers instead of for internet of things devices or solving the last mile problem,[122] and overshadowing the possibility that in some aspects there might be other more appropriate technologies.[123] Such sort of concerns have also lead to consumers not trusting information provided by cellular providers on the topic.[124] Misinformation and controversy Main article: Misinformation related to 5G technology Health See also: Wireless device radiation and health There is a long history of fear and anxiety surrounding wireless signals that predate 5G technology. The fears about 5G are similar to those that have persisted throughout the 1990s and 2000s. They center on fringe claims that non-ionizing radiation poses dangers to human health.[125] Unlike ionizing radiation, non-ionizing radiation cannot remove electrons from atoms. The CDC says "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." [126] Some advocates of fringe health claim the regulatory standards are too low and influenced by lobbying groups.[125] An anti-5G sticker in Luxembourg. Many popular books of dubious merit have been published on the subject, including one by Joseph Mercola alleging that wireless technologies caused numerous conditions from ADHD to heart diseases and brain cancer. 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