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6G: эволюция или революция?: комплексный взгляд на сотовую связь, Wi-Fi, вычислительную технику и коммуникации

6G: эволюция или революция?: комплексный взгляд на сотовую связь, Wi-Fi, вычислительную технику и коммуникации

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Описание

Существует множество потенциальных путей создания сети 6G, и на выбор могут повлиять различные факторы. В этой книге, написанной тремя экспертами в области телекоммуникаций, рассматриваются возможности и проблемы, связанные с технологией беспроводной связи следующего поколения. Будет ли 6G опираться исключительно на успешное развитие сети 5G, или же внедрение 6G приведет к технологической и инфраструктурной революции благодаря конвергенции фиксированных и мобильных сетей и сотрудничеству с гиперскейлерами для финансирования проекта?

В книге представлено убедительное видение того, как технология 6G решает проблемы, с которыми сталкивается 5G на пути к более масштабной цифровизации общества и промышленности. В ней описываются новые типы беспроводной связи, а также ...ршенствование смартфонов и способов их использования, которые произведут революцию в цифровом мире. Несмотря на то, что внедрение фазированных антенных решеток миллиметрового диапазона обеспечивает пропускную способность на уровне оптического волокна, многие сферы применения этой технологии не связаны с телекоммуникациями. Авторы также описывают революционную технологию 6G с новыми идеями в области управления спектральными ресурсами, создания дополнительных гигагерцовых диапазонов, конвергенции, конфиденциальности и базовой сетевой инфраструктуры. Кроме того, в статье рассматривается эволюция 5G и Wi-Fi к концу десятилетия как платформы для 6G, а также текущая работа над мировыми стандартами 6G. В то же время концепция «изнутри наружу» может стать определяющей для построения мобильных сетей.

6G: эволюция или революция? — в этой статье мы расскажем о том, каким может быть интернет в 2030 году и как он повлияет на 6G, особенно на его интеллектуальные уровни. В статье рассказывается об интернете и базовой сети мобильной связи, а также о том, как они изменятся в эпоху машин, благодаря Wi-Fi, связи в миллиметровом диапазоне, искусственному интеллекту и новым возможностям смартфонов.

Эта книга представляет собой информативный и заставляющий задуматься труд для исследователей, стратегов, регуляторов, ученых, инженеров, специалистов в области технологий и представителей академических кругов, интересующихся будущим коммуникационных технологий.

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Главы

Введение

стр. 1–18 (18)

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Описание

The mobile industry is at a crossroads, making now an interesting time to discuss 6G. 4G was a huge success worldwide. It was the first generation to feature a unified air interface. Moreover, the orthogonal frequency division multiplexing (OFDM) technology was efficient and adaptable in delivering mobile Internet services, especially video, which became an actual 'killer app'. Nowadays, we can get 20 GB/month for $10 or unlimited data for $15-$20 (Figure 1.1). 5G is supposed to be about so much more than just existing mobile data Internet apps; otherwise, we could have stuck with long-term evolution (LTE) and Wi-Fi. Commentators said that 5G would be much faster and have much lower latency. It would be the first generation of mobile to offer quality of service (QoS) and differentiated application classes using dedicated network resources. 5G was slated to support all non-phone devices, from autonomous cars to crop dusters, smart meters and factory robots. 5G was also designed with a core that could run on a cloud platform, making it cheaper and giving more flexible in-service creation. It embraced the idea of private networks, either created from a network slice or using shared/lightly licensed spectrum such as that made available in mobile bands, notably Citizens Broadband Radio Service (CBRS) in the United States.

От 5G к 5G Advanced

стр. 21–88 (68)

https://doi.org/10.1049/PBTE111E_ch2

Описание

There are compelling reasons to consider 6G through the lens of 5G. First, many of the visions and use cases of 5G overlap with those proposed for 6G. Second, as explained below, 5G introduced several critical radio and network innovations that are only just being rolled out (Q1 2024). It is fair to say that their commercial and technical success still remains uncertain. Not everyone universally supported the development and standardisation of 5G in its current form. Some commentators said that many of the proposed 5G use cases were niche applications, and that most could be satisfied by combining 4G cellular Wi-Fi with some regulatory changes. Nevertheless, 5G is being deployed faster than any preceding generation, but that does not yet make 5G a commercial success. This chapter also examines the technoeconomics of 5G, highlighting how commercially challenging some areas of early 6G concepts might be. Mobile networks, much as iPhones, computers, cars, and other tech stuff, continually evolve. There are several enhancements to 5G, some of which go under the banner '5G-advanced' - 6G will have to coexist with 5G for decades, and investment will only be made in 6G if benefits (in the broadest sense) outweigh the cost. This chapter concludes with a look at these 5G enhancements in the pipeline and an analysis of what light 5G can shed on the various aspects that make up 6G.

Будущий Wi-Fi

стр. 89–121 (33)

https://doi.org/10.1049/PBTE111E_ch3

Описание

Having a chapter on Wi-Fi in a book predominantly about 6G might seem slightly incongruous. However, there are good reasons to examine the latest Wi-Fi developments and standards. Wi-Fi has always carried several times more traffic than cellular networks, doing the heavy lifting of wireless connectivity indoors where macro-cellular networks are less efficient. Recent Wi-Fi developments have made much more spectrum available, promise higher maximum data rates and have the potential to offer much greater control over latency and reliability than past generations. With 5G introducing private networks enabled with advanced features such as network slicing, high reliability and low-latency support, the two technologies will offer potential solutions in the Industry 4.0 setting. In the domestic setting, 6G may deploy higher frequencies via home gateways to provide 6G services that require ultra-high data rates or processing within the network. With support from third-party network elements, many of these 6G services could also be offered within the home using Wi-Fi. Wi-Fi-cellular convergence and fixed-mobile convergence (FMC) have long been discussed. Standards exist that allow full integration of Wi-Fi networks within a cellular core but have never been widely deployed. All of these questions and tensions will form part of the development of 6G and present a strong motivation for examining recent developments in Wi-Fi and the potential implications of these. This is an exciting time for Wi-Fi, with Wi-Fi 7 certification completed January 2024, and quite a few smartphones with Wi-Fi 7 capable chipsets are appearing, such as the GooglePixel 8 Pro. Intel has also developed a BE200 Wi-Fin7 card, and the expectation is that the iPhone 16 Pro will also support Wi-Fi 7. The chapter begins with a brief history of Wi-Fi and the origins of the critical differences with cellular networks. It then describes the key innovations in the current Wi-Fi 6 generation and its extension into the 6-7 GHz band in 6E. The following section then evaluates Wi-Fi 7. This introduces significant new features supporting higher throughput, lower latency and improved reliability. Wi-Fi 8 is focused on further improving reliability by reducing interference, enhancing coordination and offering better latency and packet delivery bounds. This is due to complete standardisation in 2028, and Wi-Fi 8 devices will be commonplace around the time 6G is scheduled to appear (2030). The chapter then looks at Wi-Fi using mmWave frequencies, describing the emerging standards and potential use cases. The penultimate section describes ways Wi-Fi and cellular can be coupled. Finally, a brief look at the future of Wi-Fi with AI and sensing is likely incorporated into future standards.

Будущее Интернета

стр. 123–167 (45)

https://doi.org/10.1049/PBTE111E_ch4

Описание

This chapter examines the nature of the devices and the applications accessing the future Internet to understand the requirements and potential innovations unlocked by 6G and future Wi-Fi supported by the broadband access network and its capabilities. Understanding the needs of a broad range of application requirements will lead to understanding the requirement for 6G and where to draw the line to avoid a 'point case' setting an expensive requirement. Therefore, we examined a comprehensive body of academic and industry studies to find quantitative evidence to specify the requirements and the impact of these future Internet applications on the network.

Возможности 6G в «Индустрии 4.0» и роль Wi-Fi

стр. 169–195 (27)

https://doi.org/10.1049/PBTE111E_ch5

Описание

Mass production has a significant role in shaping the modern world. It has driven economic growth and development, creating affordable goods that have increased our standard of living and spurred technological innovation. However, industry and society must address the challenges of a scarcity of resources, the impact of industry on the environment, the disruption of global supply chains and labour shortages. Industry 4.0 aims to address all these issues.

6G — определение, основанное на мнениях организаций по стандартизации, представителей отрасли и научных кругов

стр. 199–242 (44)

https://doi.org/10.1049/PBTE111E_ch6

Описание

Since 2017, thousands of researchers and developers across multiple countries have been collaborating to develop a new mobile system for potential release in 2030 for the sixth generation. While we have yet to reach the midpoint of 5G, we are already beyond the beginning of the 6G journey with substantial research activity since 2017 in China with the Chinese IMT-2030 (6G) Promotion Group and with the European Hexa-X project, which began in 2018. In other regions, leading collaborations such as the North American Next G Alliance (NGA) have proposed concrete 6G technology roadmaps [1] with MOUs with the European Hexa-X project and Japan's Beyond 5G Promotion Consortium (B5GPC). There is also broad agreement on the key technologies and research areas for 6G worldwide. In this chapter, we consider the European Hexa-X project as an exemplar of the direction of 6G, recognising that there is also brilliant work in other regions following similar approaches and sharing their results. By considering the details of one of these mature programmes, Hexa-X, we will gain insight into what 6G is, its use cases, and the key underlying technologies. It will also explain whether it is solely an evolution from 5G Advance or whether it also brings about revolutionary features that excite the world.

Радикальный подход к управлению использованием спектра

стр. 243–286 (44)

https://doi.org/10.1049/PBTE111E_ch7

Описание

The electromagnetic (EM) spectrum is a limited natural resource. Radio frequencies are part of the EM spectrum with an internationally agreed upper limit of 3 THz. However, for the past century, our exploitation of the radio spectrum has focused mainly on just the 10 GHz of this spectrum, with minimal use above 6 GHz and virtually none above 100 GHz. While each generation of mobile technology has required wider channel bandwidths for higher speed and greater capacity, this has inevitably driven us to use higher frequencies in the belief that there is little available spectrum at lower frequencies. But, as regulators are becoming increasingly aware that, in most places, the radio spectrum is underutilised, can we find ways to access additional bandwidth without having to climb the 'spectrum staircase?' The era of popular radio use commenced in 1906 when Reginald Fessenden broadcasted an hour of talk and music for technical observers in Massachusetts, USA. The first commercial broadcasting station, KDKA, was established in Pittsburgh, USA, 14 years later. Until the 1980s, wireless use was primarily confined to the first 6 GHz of the EM spectrum for broadcast services, radio communications, mobile and Wi-Fi. However, the launch of satellite TV in the same decade pushed us beyond 2 GHz for popular broadcast and wireless services, with also the advent of 2G mobile and Wi-Fi. During this period, regulators worldwide allocated the entire 275 GHz of the EM spectrum to a range of commercial, engineering and scientific services, with minimal use over 95 GHz. Yet, human radio use remained mainly within the first 6 GHz, with only a fraction of the remaining 90 GHz utilised. The upper limit of the radio spectrum was legally defined as 275 GHz until recently. Still, it has now been extended to 3 THz to acknowledge the potential for scientific research in this region. Chapter 8 will delve into the spectrum requirements for 6G, including using mmWave spectrum above 100 GHz. This chapter explores the management of the radio spectrum, the extent of the current underutilisation and the current inefficient use. In particular, virtually all radio systems use propagation models to establish the system range and performance and avoid and manage interference with other users. These band-specific models can lead to inefficiencies of between 50% and 70%. We propose a radical approach to improving spectrum efficiency using weak signal beacon technology for propagation reporting, avoiding using a propagation model. Using weak signal beacons implemented in the transmitters can deliver a paradigm shift in spectrum management, mainly when implemented within a shared spectrum system, like Citizens Broadband Radio Service (CBRS). This approach has the potential to massively improve spectrum efficiency, using real-time propagation measurements to assign resources and carry out real-time interference remediation efficiently. Using the best spectrum below 3 GHz for mobile could yield an additional 1.9 GHz for 6G alone. Reframing 3G and 4G bands while moving TV terrestrial broadcast to broadband could further enhance this figure to 2.5 GHz. This could allow most 6G use cases to be supported on existing infrastructure apart from those for extreme performance (10-100 Gbit/s wing cm and mmWave spectrum). Furthermore, this new approach can be applied across the whole EM spectrum but would have significant utility below 10 GHz. This chapter shows how such a scheme could be applied to sharing the C-band between satellites and mobile users (arguably one of the most challenging cases to consider) before examining how the approach could be extended to the entirety of the radio spectrum. If this ambitious vision could be achieved, its economic impact would far dwarf any improvement in spectral efficiency arising from any new air-interface options that could be considered for 6G.

Миллиметровые и терагерцовые волны — «оптические волокна в воздухе»

стр. 287–327 (41)

https://doi.org/10.1049/PBTE111E_ch8

Описание

We are close to exhausting the valuable radio spectrum for mobile and wireless communications below 6 GHz with a rising tide of application speed in each new generation demanding greater channel bandwidth. One of the leading technology drivers supporting increased speed using this scarce resource has been improved spectral efficiency, but even here, we are very close to the Shannon limit. Recent trends in mobile and Wi-Fi generations have shown minor incremental spectral efficiency improvements in both the direct channel and the use of power-hungry multiple input and multiple output (MIMO) base stations for mobile networks. Nevertheless, mobile data is still growing at a compound annual growth rate of 21% [1], which drives us up the spectrum staircase to use even higher frequencies.

Конвергенция 6G

стр. 329–362 (34)

https://doi.org/10.1049/PBTE111E_ch9

Description

For more than two decades, people have discussed the concept of convergence in the telecommunications industry, specifically the convergence of fixed and mobile networks. However, apart from mergers and acquisitions between fixed and mobile operators, there has been little to no progress. However, with the advent of 6G technology, we may finally see a new form of convergence between fixed and mobile networks.

Non-terrestrial networks (NTNs)

p. 363–388 (26)

https://doi.org/10.1049/PBTE111E_ch10

Description

In this chapter, we move away from terrestrial networks (TNs) covering cellular and Wi-Fi to look at non-terrestrial networks (NTNs). NTNs include satellites, drones and high-altitude platforms (aircraft and balloons). There has been much debate about the possible role of satellites in 5G and 6G [1-4], and the first part of the chapter examines the different types of satellites based on their orbital height and associated coverage, latency and capacity. There has been a significant investment in low Earth orbit (LEO) satellites in recent years, typified by Starlink [5]. These satellites potentially offer a substantial uplift in capacity due to their high numbers and lower latency than higher geostationary satellites. To try and answer critical questions about which applications these satellite constellations will be suitable for, we analyse the coverage, capacity and cost of these LEO systems. The chapter then examines drones, or uncrewed aerial vehicles (UAV), and high altitude platforms (HAPs). These have also been suggested for various applications, including temporary coverage boosts and rural connectivity. The following section examines how NTNs might connect to cellular networks and describes the evolving standards. The application section explores possible use cases that NTNs might enable in 5G and 6G. There are many challenges for NTNs, and the final section examines these, including the Kessler syndrome, which might pose an existential threat to satellite constellations.

A radical core network for 6G

p. 389–425 (37)

https://doi.org/10.1049/PBTE111E_ch11

Description

The discussion about the future of 6G is not only limited to new radio hardware but also includes the Mobile Core. This is even more significant if 6G has no new radio interface, as suggested by the Next Generation Mobile Networks Alliance. This chapter explores the two options for the 6G core network, whether it is an evolution of the 5G core network or a completely new system. It provides an analysis of both options and their respective advantages and disadvantages.

Privacy-enhancing technology and security for 6G

p. 427–450 (24)

https://doi.org/10.1049/PBTE111E_ch12

Description

Trustworthiness is a theme of many of the 6G research and standards projects described in Chapter 6. Security and privacy are two essential requirements for trustworthiness. Security and privacy are often incorrectly used interchangeably, but they are treated differently in different sections of this chapter. Privacy concerns controlling personal or confidential information, e.g. who knows your bank account number. Security is about protecting IT or network assets from attacks, e.g. your bank's security against hackers. Telecom fraud, which, according to Talluri *et al.* [1], cost US$32.7 billion in 2019, is a telecom-centric use case that illustrates this. Solving the fraud detection problem requires both the protection of individuals' private data, e.g. who has called you and who you have called, and security to protect the telecom networks. Section 12.2 examines the use of privacy-enhancing technology (PET) to give privacy in 6G. Section 12.3 examines 6G security challenges and potential solutions.

Artificial intelligence for 6G

p. 451–475 (25)

https://doi.org/10.1049/PBTE111E_ch13

Description

The combination of artificial intelligence/machine learning (AI/ML) technology with the upcoming 6G wireless technology brings about a unique synergy that surpasses the individual strengths of each technology. The integration of AI/ML with 6G has the potential to redefine wireless communication by providing real-time data analysis and decision-making abilities, which complement 6G's high-speed and low-latency network. This synergy enables predictive analytics to identify and fix network issues before they impact the service, thereby enhancing the reliability and performance of 6G networks. Designing, building, operating and optimising cellular networks requires significant skills, time and application of 'rules of thumb'. The multidimensional nature of the problem and the potential amount of data describing the network and its operation makes it difficult for humans to optimise, but it is an ideal candidate for the application of ML and AI. AI can improve network energy efficiency, automate system management, manage radio and compute resources to meet Service Level Agreements (SLAs), detect anomalies caused by faults or cyber-attacks and predict future traffic and network performance. 6G could embed AI in its standards to create better networks. Networks that automatically optimise themselves to meet the requirements of network operators and customers. AI could lower power consumption when demand is low, give higher bit rates only when required and trade-off latency and error rates according to an application's requirements. AI can optimise the design of network protocols on the fly. Semantic communications are data compression technologies powered by AI that use the context and goals of communications to reduce the amount of data that needs to be transmitted by orders of magnitude. This chapter summarises some of the critical applications of AI to 6G and its implications. It also examines 6G mobile network operators (MNOs) offering AI services to their customers that exploit the network's topology and hardware to accelerate federated learning, exploit data from joint sensing and communication (Chapter 14) and leverage multi-access edge computing to process data. There are many novel and exciting applications of AI to 6G networks beyond the mundane but essential optimisation and operation of networks also explored in this chapter. AI is a scientific discipline with a large set of concepts and vocabulary of terminology unfamiliar to telecommunications network people. This chapter focuses on the application of AI to mobile networks and avoids an in-depth explanation of AI. Box 13.1 summarises common AI technologies and terms.

Joint communication and sensing (JCAS) in 6G networks

p. 479–494 (16)

https://doi.org/10.1049/PBTE111E_ch14

Description

As 5G technology advances, the new 6G network is expected to improve upon the three principal features of enhanced mobile broadband (eMBB) for immersive communications, critical communications requiring ultra-low latency and reliability (URLLC) and massive machine-type communications. However, some vital differences will set 6G apart from its predecessor. One of the most revolutionary features of 6G is radio sensing and positioning capabilities. Although defined in 5G standards, they were never enacted at scale. Nevertheless, 6G is expected to offer even better positional accuracy on its launch than the 5G standards. The importance of sensing is seen as a bridge between the three worlds of Human, Physical and Digital - the vision of the 6G as defined by one of the many significant research programmes, the EU - Hexa-X.

iPhone 2030 (6G) and other devices

p. 495–506 (12)

https://doi.org/10.1049/PBTE111E_ch15

Description

Every decade, the arrival of new mobile generations brings fresh capabilities, but the most significant moment in wireless communications for consumers occurred on 29 June 2007. It was the day when Steve Jobs, in his legendary keynote at the MacWorld Expo, unveiled the original iPhone as 'an iPod, a phone and an internet communicator'. This game-changing device altered the course of mobile usage and prompted UK mobile network operators to explore Wi-Fi offload at public hotspots due to the exponential surge in mobile data. The iPhone emerged independently from the traditional cellular industry and demonstrated that a revolutionary end device could shape the direction of wireless communications for well over a decade. This chapter delves into the technological trends that may define an iconic smartphone in 2030, envisioning a future iteration like the hypothetical Apple 'iPhone 2030 6G'. This exploration provides insights into the potential user experience and sheds light on the network requirements that may arise for both 6G and Wi-Fi 8/9.

What could 6G be?

p. 507–565 (59)

https://doi.org/10.1049/PBTE111E_ch16

Description

The book aims to answer one of the most significant questions in mobile: what will the upcoming sixth mobile generation (6G) be like? Could it be an extension of the already existing 5G Advanced, or will it be a completely new technological revolution that supports an array of new applications and services? The European Union has proposed this question as the foundation of its research project portfolio, which six other regional global partners are addressing. The goal is to contribute to the technical definition of 6G in

2027, which will be released as part of Release 21 of 3GPP. And, of course, we must remember the economic challenges facing mobile network operators (MNOs), particularly today in 5G.

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Back Matter

p. 567–589 (24)

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