Computer Networks 129 (2017) 392–398

Contents lists available at ScienceDirect

Computer Networks

journal homepage: www.elsevier.com/locate/comnet

Resource management for future mobile networks: Architecture and technologies

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ARTICLE INFO

Article history:
Received 15 December 2016
Revised 26 February 2017
Accepted 6 April 2017
Available online 7 April 2017

Keywords:
5G
Resource management
Cloud-based user-centric network
Interference management

ABSTRACT

Compared to fourth-generation (4G) cellular systems, fifth-generation (5G) wireless communication systems face ever-increasing demand for spectral efficiency, energy, high data rates, and throughput as required by new devices and applications. To address these challenges, 5G wireless networks must adopt ultra-dense and heterogeneous networks (HetNet), which render interference and resource management (RM) even more challenging than they are today. In this article, we first review various 5G wireless network architectures proposed in the literature before discussing key 5G wireless technologies for RM. We focus specifically on RM research, which includes spectrum assignment, resource and channel allocation, power control, and interference management based on user-centric cell schemes. Finally, we present a cloud-based user-centric network architecture with emphasis on the networks formation, RM, and interference signal joint-processing via cluster technology to provide higher throughput.

1. Introduction

In order to meet the demands of future networks and the pursuit of higher performance for mobile communications, a series of groups such as the International Mobile Telecommunication (IMT) System for 2020 and Beyond (IMT-2020), the International Telecommunication Union (ITU) under the United Nations in 2012 [1], the Mobile and Wireless Communications Enablers for the Twenty-twenty Information Society, and the 5G Infrastructure Public Private Partnership have officially presented the 5G mobile network and standardization aspects thereof. The current goal is to reach a consensus on demand and index and to achieve unity in concept, prototype, and views on key technologies. Compared to 3G and 4G, 5G represents a series of innovative technologies with an emphasis on integrity and comprehensiveness to advance and complement existing systems. Wireless access technologies including 3G, 4G, and WI-FI remain essential components of 5G [2–4].

Most mobile communications industries have begun to express consonant opinions of emerging 5G technologies. A recent ITU-Radiocommunication Sector Draft Recommendation [5] on IMT-2020 notes that the wireless spectrum resource requirements for 5G wireless networks are primarily a result of growing demand for system capacity that accompanies a variety of new application scenarios. 5G technical requirements include peak data transmission rates greater than 10 Gbps, village edge data transmission rates of at least 100 Mbps, and a 1 millisecond end-to-end delay. The Draft Recommendation also identifies three key usage scenarios for 5G: (1) enhanced mobile broadband; (2) ultra-high reliable and low-latency communication; and (3) massive machine-type communications. The imminence of these scenarios presents fundamental challenges [6] for existing cellular networks, including but not limited to growth capacity requirements, higher data rates, heavy network traffic, excellent end-to-end performance, user coverage in hot-spots and crowded areas, lower latency, and increased energy consumption.

To address these challenges, 5G wireless networks are expected to adopt a multi-tier heterogeneous architecture to enhance coordinated multipoint transmission (CoMP) or reception, wherein devices communicate directly (i.e., either machine-to-machine or device-to-device (D2D)) to serve user equipment (UE) with different quality-of-service (QoS) or quality-of-experience (QoE) requirements. Damnjanovic et al. [7] discusses an alternative strategy, where low power nodes are overlaid within a macro network based on different access technologies. The macro base station (BS) is based on cellular technology, and low power access points rely on WLAN or local IP access. When numerous devices are accessed via ultra-dense networking, effective interference management and

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http://dx.doi.org/10.1016/j.comnet.2017.04.007
1389-1286/

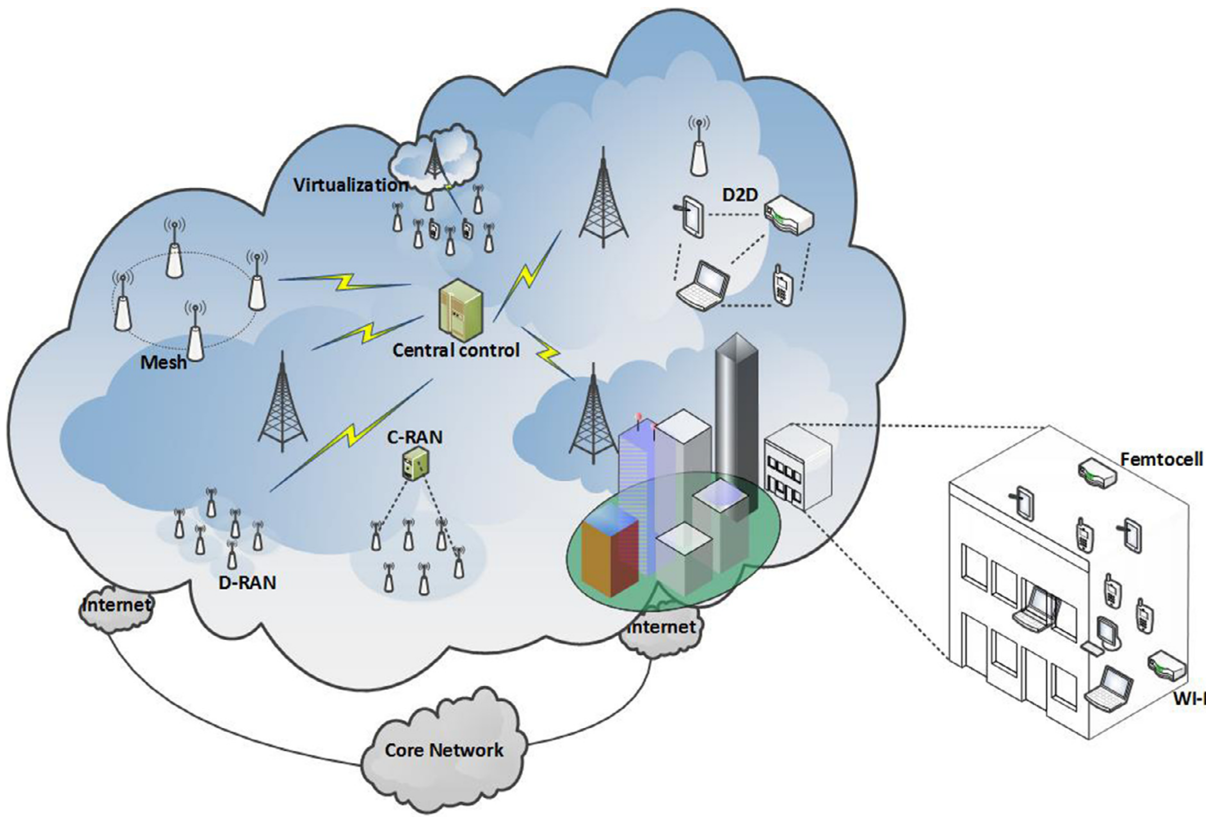

Fig. 1. The potential 5G wireless HetNet architecture.

resource optimization facilitates security, IoT transmission stability, and system robustness. The three key usage scenarios can be adequately supported by dynamic and heterogeneous networks. Macro cells and small cells have different data traffic demand dynamics and must adjust downlink and uplink resource allocation accordingly. Having reviewed recently released architectural models and research, the present papers proposed 5G wireless HetNet architecture is shown in Fig. 1 Inter-cell interference is a constraining factor to improving QoS in ultra-dense and heterogeneous networks. Many operators and equipment manufacturers have released user-centric cells, which are outfitted with comprehensive seamless switching technologies in an effort to ensure optical fiber access speed and "zero" delay for users [8]. Macro BS technology and small cell with joint transmission are effective at reducing inter-carrier interference. Large-scale and ultra-dense deployment of small cells, combined with macro cells, separate the control and user planes to ensure efficient use of the high-frequency spectrum. To this end, Artemis Networks has implemented the pCell virtual cell model [9]. Yet interference enhancement between cells, conversion of the interference signal, and effective RM remain popular research areas in light of limited radio resources. For user-centric networks, many challenges arise in clustering design, precoding, and training for channel estimation due to different users conflicting requirements. To resolve these issues, a central processor (CP) is necessary. The CP can be deployed under the architecture of cloud radio access networks (C-RAN), which was recently proposed as a pivotal technology for future 5G [3]. Specifically, in order to design joint precoding of multiple BSs, where each BS may belong to different clusters simultaneously, the CP should gather instantaneous channel information from all BSs and all users within cooperative clusters throughout the entire network.

In addition, certain factors will influence radio RM policies, namely small cell deployment, resource allocation, fairness, and load balance problems, all of which are highly complex. Radio RM research tends to focus on power control, channel allocation, scheduling, handover, access control, cell association, interference management, load control, coded modulation, etc. In this paper, we focus on a radio RM model rooted in cloud-based user-centric network schemes to provide higher throughput, improved data rates, increased capacity, and shorter delays to resolve problems with cell edge coverage for future mobile networks.

2. Key 5G technologies of resource management

Compared with 4G, 5G will support more diverse scenarios, integrate multiple wireless access methods, and make full use of the low-frequency and high-frequency spectrum. In addition, 5G will meet the needs of flexible network deployment and operations and improve spectrum, energy, and cost efficiencies.

2.1. Planes of the new 5G network architecture

In 2015, IMT released a white paper outlining 5G wireless network and technology architectures in the 2015–2020 (5G) summit [10]. Meetings were held to discuss relevant aspects of 5G wireless networks, including increasing demands on network capacity to support network quality, flexibility, and overall development trends in intelligence. Two factors, tied respectively to technical innovation and collaborative development, warrant special attention in 5G wireless networks: the infrastructure platform and network architecture. Compared to the current dedicated hardware infrastructure platform, that of 5G wireless networks relies heavily on the Internet and virtualization technology to address issues related to resource allocation and high costs. Based on the separation of control and data planes, the new network architecture aims to simplify the structure of core networks, improve access performance