Guest Editorial Caching for Communication Systems and Networks—Part II

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WELCOME to the second part of the IEEE JSAC special issue on Caching for Communication Systems and Networks. The goal of this special issue is to present the multiple facets of caching, from information theory to networking and services, and explore the role of memory in communications. This is a very timely topic due to recent technological and theoretical advances summarized in the tutorial paper that appears in the first part of the issue [1].

The concept of caching was introduced more than 40 years ago for enhancing the performance of computer systems [2], and since then has been used to support content delivery in the Internet, and recently over wireless networks [3]. As the user demand for (mobile) content grows fast, caching is expected to play a very important role in future communication systems and networks. Indeed, there is consensus today that caching can increase network performance, reduce expenditures for operators and infrastructure owners, and improve the quality of services offered to users.

Therefore, it is not surprising that a number of different industries focus today on content caching, or leverage this technique in order to improve their services. Prominent examples include content distribution networks such as the Akamai CDN; cloud storage services offered by Amazon; service-specific caching networks as those deployed by Google and Facebook; and caching techniques tailored to wireless networks as those proposed by Cadami. Furthermore, 3GPP working groups have proposed standards for enabling caching at the Radio Access Network or even at base stations, hence opening new opportunities for caching in wireless networks. These developments call for further research on caching theory and caching architectures.

This special issue has called for papers from the entire spectrum of caching research, aiming to present the latest developments in the various caching topics, and to offer a unified view on this important subject. We were delighted to receive 118 papers spanning all research topics in caching (see Table I), and using different tools such as information theory, optimization theory, large-scale simulations, data analysis and experiments. Following a thorough and very competitive review process 33 papers were accepted and are presented in this double special issue. We hope that this selection of papers will highlight recent findings in caching and contribute towards the further development of this important tool. To this end, the first part of the issue includes also a tutorial [1].

TABLE I
CACHING TOPICS STATISTICS

Topic and Keywords	Papers
Information-theoretic Caching Analysis	16
Fundamental Limits of Caching	16
Coded Caching Design with Practical Constraints	12
Scaling Laws of Cache Networks	7
HetNet and Device-to-device Caching	18
Edge Caching, Cooperation and Femtocaching	32
Joint Caching, Scheduling and Routing	19
Secure Caching and Privacy Preservation	6
Content Caching and Delivery	56
Algorithms for Storage Placement	17
Video caching and Streaming	14
Caching Economics	13
Caching models for ICN	12
Popularity Models and Machine Learning	9

The second part of this special double issue includes 16 papers. It begins with the paper "On coding for cache-aided delivery of dynamic correlated content" [4] which generalizes the idea of coded caching by considering correlated content items. The authors show that this correlation can be leveraged to obtain an improved lower bound for the rate-memory trade-off. Next, the paper "Cache aided communications with multiple antennas at finite SNR" [5] introduces a linear program for devising joint cache allocation and (pre-) fetching schemes that minimize content delivery delay. The proposed solution employs zero-forcing and cached interference subtraction, and hence allows each user to be served at the rate of its own channel rather than of the poorest channel in the group. Similarly, the paper "Utility optimal scheduling for coded caching in general topologies" [6] is motivated by the observation that the performance of coded caching over wireless fading channels is limited by the user with the worst fading condition. The paper suggests a new opportunistic content delivery scheduling policy in order to address this problem.

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The fourth paper in this issue, "Caching and coded delivery over Gaussian broadcast channels for energy efficiency" [7], extends coded caching to wireless broadcast channels with Gaussian noise, and studies methods that improve energy efficiency. The paper "On the effects of subpacketization in content-centric mobile networks" [8] analyzes the throughput-delay trade-offs in an ad hoc network where each node moves according to a reshuffling mobility model, and extends prior work to this scenario where subpacketization is used.

Next, the paper "Optimized base-station cache allocation for cloud radio access network with multicast backhaul" [9] uses a mixed time-scale problem to optimize cache dimensioning at the base stations and beamforming decisions, aiming to improve content delivery in C-RAN wireless networks. C-RAN is also the focus of the paper "Online resource allocation, content placement and request routing for cost-efficient edge caching in cloud radio access networks" [10]. The authors consider a cooperative system where cloud resources at the RAN can be shared, and design joint content placement and routing policies for minimizing system costs.

The paper "Hierarchical edge caching in device-to-device aided mobile networks: modeling, optimization, and design" [11] proposes the idea of improving caching policies in small cell networks and mobile devices by considering social-layer characteristics, such as mutual user interests and mobility patterns. The paper "Mobility prediction-assisted over-the-top edge prefetching for hierarchical VANETs" [12] presents traces from a vehicular ad-hoc network. It is demonstrated that prediction-enhanced content prefetching can indeed increase the network performance. In this case the predictions refer both to content popularity and the location of the vehicles.

Zhang *et al.* [13] "Energy-efficient caching for scalable videos in heterogeneous networks" consider video caching over heterogeneous networks modeled with Poison Point Processes (PPP), and study the impact of different viewing quality requirements on the network's energy efficiency. The work "QoE-assured 4K HTTP live streaming via transient segment holding at mobile edge" [14] studies HTTP-based live streaming services where mobile devices request ultra-high video quality. The authors propose a novel scheme which performs context-aware transient holding of video segments at the cache-enabled mobile edge, aiming to reduce initial startup delay and live stream latency.

The next paper in this issue "Caching with partial adaptive matching" [15], studies user request matching to caches. It compares a scheme focusing on coded server transmissions while ignoring matching capabilities, with a scheme that focuses on adaptive matching while ignoring potential coding opportunities. Next, the paper "Coded joint pushing and caching with asynchronous user requests" [16] extends the coded caching framework to an online approach that designs placement and delivery while considering user demand asynchronism.

In a different setting, the paper "ReD/LeD: An asymptotically optimal and scalable online algorithm for service caching at the edge" [17], proposes an online algorithm to address an important question in hierarchical networks: having a set of edge servers with limited storage capacity, which *services* to cache in order to reduce the network costs? The authors propose an algorithm for making such caching decisions in an online fashion, and without requiring prior knowledge of service popularity parameters.

The paper "Parallel simulation of very large-scale general cache networks" [18] studies how to efficiently simulate very large caching systems, a task known to be very compute-intensive. The authors propose model-driven techniques, and leverage very accurate approximations of caching systems that enable the simulation of caching algorithms in networks with hundreds of caches and trillions of content items. The issue is completed with the paper "Understanding scoped-flooding for content discovery and caching in content networks" [19] which designs a new technique for propagating control signals for content discovery, by building multicast trees routed at the source node. Since replica frequency is expected to relate to popularity, the authors suggest tuning the discovery radius according to content popularity.

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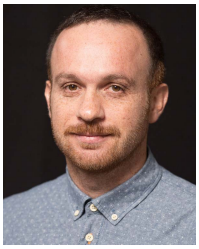

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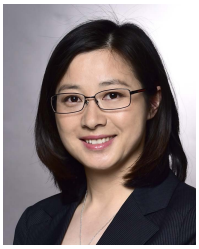

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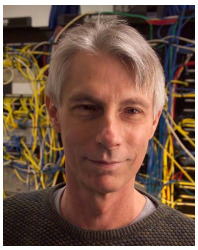

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