IEEE EMERGING TECHNICAL INITIATIVE BACKHAUL/FRONTHAUL NETWORKING & COMMUNICATIONS // ISSUE 2// VOLUME 1

IEEE ETI-BNC BLOG

FOCUS TOPIC:
BACKHAUL RELAXATION

IN THIS ISSUE

CHAIR'S MESSAGE

BY MUHAMMAD ZEESHAN SHAKIR

This is the second issue of IEEE ETI-BNC blog. While researchers and experts from industry and academia are busy in creating new game changing backhaul/fronthaul solutions for enormous traffic in 5G and beyond 5G networks, it is equally important to improve the utilization of existing backhaul/fronthaul approaches. Therefore, I would like to present backhaul/fronthaul relaxation as the focus topic of this issue. This special issue includes an editor's opinion piece on the state-of-the-art research in the focus area followed by the editor's review column where Dr. Omid Semiari reviews a recently published article which exploits content caching to reduce the backhaul traffic.

You may know already that the 4th IEEE BackNets 2018 will be organized with IEEE Globecom 2018, Abu Dhabi on Dec 13, 2018. We encourage you to submit your recent results and key findings to our workshop. .

I would like to express my special thanks to Dr. Omid Semiari form Georgia Southern University and Dr. Syed Ali Raza Zaidi from the University of Leeds for putting every effort to turn it into reality and give our blog a new "fresh look".

The blog aims to highlight key achievements of community members. Consequently, if you would like to share your recent achievements or highlight successful proposal which are of relevance to the community, please get in touch with the editors. I would like to take this opportunity to welcome any suggestions from the community members to make ETI-BNC blog more informative and interesting. You are welcome to either write to me or approach any of the editors.

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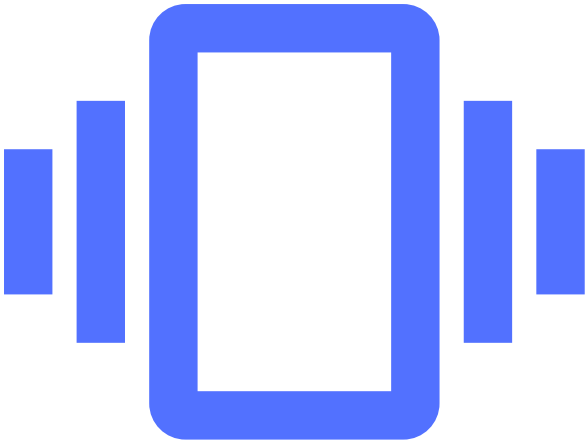
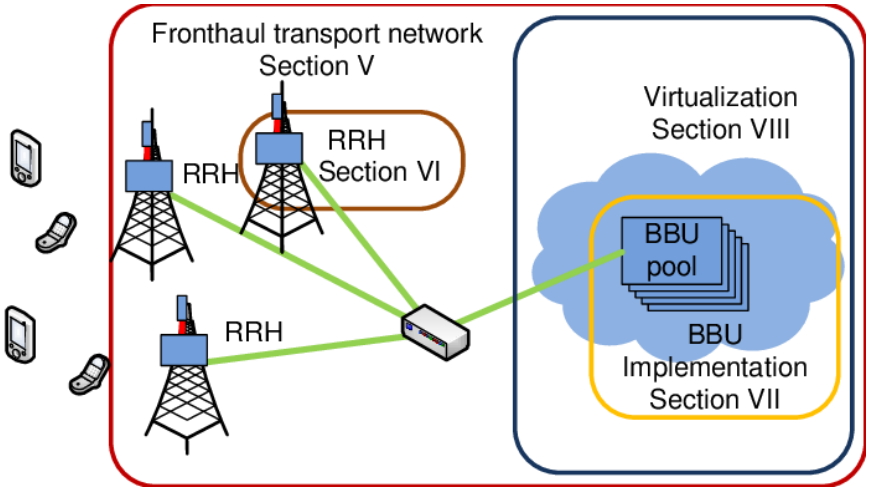
EDITOR'S OPINION PIECE

INSIGHTS



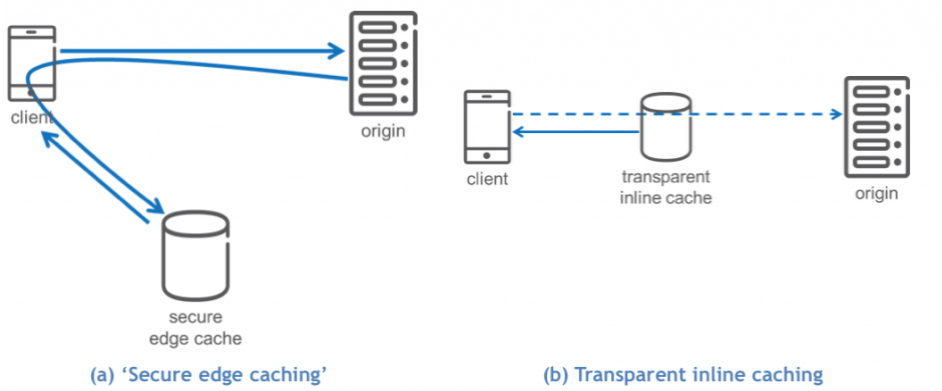
Network densification is one of the key enablers for boosting the coverage and capacity for future wireless networks. The fundamental idea behind densification stems from the aggressive utilization of spectral resources across spatiotemporal dimensions. Fundamentally, although finite, RF spectrum is infinitely renewable quantity. Nevertheless, increased density of so-called small cells also requires tighter coordination between the cells. The coordination between small cells enables better mobility and interference management. Nevertheless, this comes at the cost of increased backhaul traffic which in turn requires the development of backhaul relaxation mechanisms.

As outlined in [1]-[2], performance gains of the orders of 50-100 percent can be realized through **multi-cell cooperation** schemes such as joint transmission coordinated multi-point (JT-CoMP) transmission. Backhaul relaxation is an important feature when considering multi-cell cooperation in future wireless networks. In [2] authors estimate that the backhaul traffic resulted in 100s of Gbps when considering JT-CoMP transmission. Consequently, backhaul relaxation becomes a fundamental enabler for facilitating multi-cell cooperation. Backhaul data compression and techniques deriving its roots from compressive sensing have been frequently adapted to address this challenge. For instance, in [3] authors consider CoMP transmission scheduling problem with multi-element base-stations cooperating over the backhaul to serve mobile users furnished with a single antenna. The problem translates into the joint design of transmit beamformers and user data allocation at BSs to minimize the backhaul the data transfer which is subject to given quality-of-service (QoS) and per-BS power constraints. The author demonstrates that the problem can be cast into a zero-norm minimization and thus compressive sensing techniques can be extended to solve the problem.



Cloud RAN Architecture [14]

Cloud radio access networks or also called centralized radio access networks (C-RANs) essentially empower cell-less architecture which enables better interference coordination. One of the key features of such networks is user-centric clustering [4] and joint transmission using remote radio heads (RRHs). In such an architecture the baseband processing is migrated to the remote control units (CUs). This is facilitated by the network of backhaul links which carry compressed information between RRHs and CUs. In such an architecture backhaul data compression plays a vital role. One of the important design issues is how to realize data compression for general multi-hop backhaul networks. In [5] authors investigates efficient backhaul compression strategies for the uplink of C-RANs with a general multi-hop backhaul topology. The study first outlines the performance of baseline multiplex and forward scheme where RUs (radio units) are forwarded uncompressed data from CU. As expected, the strategy yields worst-case performance bounds as significant performance degradations are unavoidable for ultra-dense deployments. The authors present an alternative scheme where RUs decompresses the received bit streams and performs linear in-network processing of the decompressed signals. The optimal design for both scenarios is explored in details. In brief, backhaul compression mechanisms are an essential ingredient of future wireless network deployments. Interested readers are directed to [6] for a detailed account of backhaul and front haul requirements for CRAN.



Courtesy: Ericsson https://www.ericsson.com/research-blog/5g-media-delivery/

From the cellular uplink perspective, edge caching has emerged as one of the key enablers for the backhaul relaxation. In [7] authors extend content-centric networking for realizing backhaul relaxation through content caching. The authors outline the role of in-network caching towards information-centric architecture, outlining the metrics required to quantify the performance of such network architectures. The authors also present a comprehensive study on content placement mechanism in caches. Following the several important results in [8]-[10], there has been significant interest in the literature on wireless content caching. Recent studies [11]-[13] all explicitly account for backhaul relaxation through content caching.

Besides content caching and backhaul data compression, there are several other network optimization techniques including traffic grooming techniques which have been presented in the literature for enabling backhaul relaxation. Nevertheless, there are still several technical challenges specifically in the practical adaptation of the proposed mechanisms. To that end, we encourage the community to share their views and recent results with us in this important and emerging area for future issues.

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BACKHAUL RELAXATION

EDITOR'S SPOTLIGHT COLUMN

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IEEE TRANSACTION ON WIRELESS COMMUNICATION, FEB. 2018

EDGE-CACHING WIRELESS NETWORKS: PERFORMANCE ANALYSIS AND OPTIMIZATION

Authors: Thang X. Vu, Symeon Chatzinotas, and Bjorn Ottersten

OBJECTIVES

This work focuses on performance analysis and optimization of edge-caching in emerging wireless networks. The authors have studied the performance of coded and uncoded caching strategies for scenarios in which both base stations and users are capable to edge-caching. The main objectives of the analysis presented in this work are: 1) Understanding backhaul and access throughput requirements as functions of cache sizes; and 2) Maximizing the energy efficiency of the network, subject to users' minimum data rate requirement; and 3) Minimizing the content delivery time under both coded and uncoded caching strategies.

RELEVANCE

The emergence of new wireless services such as social networking and uncompressed video streaming has strained the capacity of wireless networks. Coupled with increasing number of users and smart devices, managing such substantial traffic at both wireless access and backhaul networks will be very challenging. While cloud radio access networks (C-RANs) architectures and small cells are seen as attractive solutions to boost the capacity of wireless networks, these techniques alone will not be sufficient to manage the traffic at peak hours. Therefore, new techniques are required to optimize the network to meet the data rate and latency requirements of emerging bandwidth-intensive services.

In this regard, edge-caching is an enabling technique that allows to place popular content at the base stations or user devices (during off-peak periods) when sufficient network resources are available. Accordingly, when a user request a (popular) cached content during the peak traffic hours, the base station can directly serve the user, without requiring to fetch the content over the backhaul network. Thus, one properly implemented, edge caching can yield “backhaul relaxation” and address the network congestion during peak traffic hours.

KEY CHALLENGES

To reap the benefits of edge caching, there is a need for joint design of “content placement” strategies and “content delivery” in order to effectively serve users, while reducing the traffic from the backhaul network. Although substantial works have been done to design caching in wireless networks, the prior art either focuses solely on the uncoded caching strategy, or studies coded caching separately from the signal transmission during the content delivery phase.

KEY RESULTS

This work presents a comprehensive analysis of design and performance evaluation of edge caching in wireless networks. Main findings of this work can be summarized as follows:

• The authors have derived closed-form expressions for the required throughput at the backhaul and access networks to implement both coded and uncoded caching strategies. Given that the coded caching strategy employs multi-casting of a coded message to a group of users during the delivery phase, the authors have used physical-layer multicasting to precode the data for the coded caching strategy. Accordingly, the authors have analyzed the energy efficiency, as a key performance metric, under both coded and uncoded caching strategies. This analysis disregards the energy consumption for the content placement and only considers the energy efficiency during the content delivery phase. The authors have compared the performance of the two caching strategies, in terms of energy efficiency, for special cases, e.g., when all content is available at the base station (referred to as the free-cost backhaul link scenario).

• Using the derived analytical results, the authors have proposed optimization problems that maximize the energy efficiency for coded and uncoded caching strategies, subject to a rate constraint for the users. To solve these problems, the authors have proposed solutions that build on 1) zero-forcing precoding and 2) Semi-definite relaxation.

• Finally, the authors have minimized the content delivery time (average time duration for all users to receive their requested content) for both caching strategies. In this work, the backhaul delay and processing delay at base stations are considered negligible.

• Simulation results show that the uncoded caching, under the semi-definite relaxation design, achieves higher EE than the coded caching when the user cache is capable of storing up to 20% of all the files. Otherwise, the results suggest using the coded caching to achieve larger energy efficiency.

• The results also show that for all user cache sizes, uncoded caching under the semi-definite relaxation design achieves better energy efficiency than the zero-forcing method (at the expense of higher complexity).

• Modeling the content popularity distribution by the widely-used Zipf distribution, the results show that a greater Zipf exponent factor results in higher energy efficiency for both designs. This is because the content distribution, in this case, is more centralized in some files. Meanwhile, the results show that base station's cache size has smaller impacts on the system's energy efficiency compared with the user cache size.

• With regard to the content delivery time, the results demonstrate that when the user cache size is small, the uncoded caching strategy delivers the requested files faster than the coded caching method. However, when the user cache memory is capable of storing more content, the coded caching strategy is more efficient than the uncoded caching.

• Regarding the impact of network size, for a small number of users, the uncoded caching strategy outperforms the coded caching. As the network size increases, the coded caching achieves a better performance, as the total cache size in the network effectively increases.

OUTLOOK

This work have presented a comprehensive analysis of coded and uncoded caching strategies for content delivery in wireless networks. The network requirements, in terms of backhaul and access throughput, have been analytically derived. Moreover, the network performance metrics, particularly energy efficiency and content delivery time, are optimized. The analysis provided in this work can be extended by considering different (energy or spectral) backhaul constraints when designing the caching
algorithms. Another direction is to study the coded caching under non-uniform content popularity distributions among users. This will require to redesign both cache placement and delivery phases in order to take into account users' unique preferences.

Call for Papers

IEEE Globecom 2018

4TH IEEE WORKSHOP ON NEXT GENERATION BACKHAUL/FRONTHAUL NETWORKS - BACKNETS 2018

https://sites.google.com/site/backnets2018/home

December 13th, Abu Dhabi, U.A.E.

Workshop Scope: Technically endorsed by IEEE ComSoc Emerging Technical Initiative Backhaul/Fronthaul Networking and Communication (ETI-BNC), **Workshop on Next Generation Backhaul/Fronthaul Networks** – BackNets has been organized with the IEEE Flagship conferences since last 3 years. BackNets has been now considered as an exclusive venue to accelerate the research and development in this area by providing a platform for both academic and industrial stakeholders to present and discuss innovative backhaul/fronthaul solutions and cutting-edge research and development. BackNets 2018 is expected to provide an opportunity for exchanging new ideas and creating new space for innovative game-changing backhaul solutions in solving the challenging problems of smart backhauling/fronthauling for 5G and beyond 5G (B5G) networks. BackNets 2018 intends to cover wide spectrum of underlying backhaul/fronthaul themes including, but not limited to:

- Requirements and limitations for backhaul/fronthaul communications and networking
- Emerging 5G technologies for smart backhaul/fronthaul solutions
- Spectrum management for backhaul/fronthaul communications and networking
- Backhaul/fronthaul deployment, standard and spectrum policy issues

Workshop Organizers

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Important Deadlines

- Paper submission deadline: 15 June 2018
- Acceptance notification: 31 July 2018
- Camera-ready paper: 30 August 2018
- Workshop Date: 13 December 2018

Invited Speakers

Merouane Debbah – Huawei, France
Xavier Costa – NEC, Germany
Markus Gruber – Nokia, DE/Stuttgart
Wei Yu - U. of Toronto, Canada
Mirsad Cirkic – Ericson Research, Sweden
Tazi Abdellah - co-chair of 1914WG/ ATT Mobility, US

Paper submission: https://edas.info/newPaper.php?c=25042&track=91821

Industrial News

On 18th May, a consortium of twenty industry-leading companies, including NEC, announced the successful completion of a nearly three-year European Union Horizon 2020 project aimed at developing a 5G integrated backhaul and fronthaul transport network. After nearly three years, the project, 5G-Crosshaul, is now the de-facto concept for the 5G integrated fronthaul/backhaul transport network.

The 5G-Crosshaul consortium was selected in 2015 to develop a 5G integrated backhaul and fronthaul transport network that enables a flexible and software-defined reconfiguration of all networking elements in a multi-tenant and service-oriented unified management environment. The transport network flexibly interconnects distributed 5G radio access and core network functions hosted on in-network cloud nodes. This is achieved through the implementation of a control infrastructure using a unified, abstract network model for control plane integration and a unified data plane encompassing innovative high-capacity transmission technologies, as well as novel deterministic-latency switch architectures.

For more information on the 5G-Crosshaul project, please visit http://5g-crosshaul.eu/

Contributed By

XAVIER COSTA-PEREZ

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Dr. S. A. Zaidi is a University Academic Fellow (Assistant Professor) at the University of Leeds in the area of wireless communication & sensing systems. From 2013-2015, he was associated with the SPCOM research group working on the United States Army Research Lab funded project in the area of Network Science. From 2011-2013, he was associated with the International University of Rabat working as a Lecturer. He was also a visiting research scientist at Qatar Innovations and Mobility Centre from October-December 2013 working on QNRF funded project QSON. He received his Doctoral Degree at the School of Electronic and Electrical Engineering at Leeds and was awarded the G. W. and F. W. Carter Prize for best thesis and best research paper. He has published more than 90 papers in leading IEEE conferences and journals. From 2014-2015, he served as an editor for IEEE Communication Letters. He was also lead guest editor for IET Signal Processing Journal's Special Issue on Signal Processing for Large Scale 5G Wireless Networks. Currently, he is an Associate Technical Editor for IEEE Communication Magazine. Dr. Zaidi is EURASIP Local Liaison for United Kingdom and also General Secretary for IEEE Technical Subcommittee on Backhaul and Fronthaul networks. He is also an active member of EPSRC Peer Review College.

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Omid Semiari is an Assistant Professor at the Electrical and Computer Engineering Department at Georgia Southern University. He received the BSc and MSc degrees in electrical engineering from the University of Tehran, in 2010 and 2012, respectively, and the PhD degree from Virginia Tech, in 2017. His research interests include wireless networks, millimeter wave communications, context-aware resource allocation, matching theory, and machine learning. In 2014, Dr. Semiari has worked as an intern at Bell Labs, in Stuttgart, on anticipatory, context-aware resource management in cellular networks. In 2016, he has joined Qualcomm CDMA Technologies (QCT) for a summer internship, working on LTE-Advanced modem design. Dr. Semiari is the recipient of several research fellowship awards, including DAAD (German Academic Exchange Service) scholarship and NSF student travel grant. He has actively served as a reviewer for flagship IEEE Transactions and conferences and participated as the technical program committee (TPC) member for a variety of workshops at IEEE conferences, such as ICC and GLOBECOM. Currently, he serves as a member of editorial board for the IEEE ComSoc TCBNC blog and IEEE ComSoc Technical Committee/TCCN Newsletter.

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Muhammad Zeeshan Shakir is an Assistant Professor at the University of the West of Scotland (UWS), UK. Before joining UWS in Fall 2016, he has been working at Carleton University, Canada, Texas A&M University, Qatar and KAUST, Saudi Arabia on various national and international collaborative projects. Most of his research has been supported by industry partners such as Huawei, TELUS and sponsored by local funding agencies such as Natural Sciences and Engineering Research Council of Canada (NSERC), Qatar National Research Fund (QNRF) and KAUST Global Research Fund (GCR). His research interests include design, development and deployment of diverse wireless communication systems, including hyper-dense heterogeneous small cell networks, Green networks and 5G technologies such as D2D communications, Networked-flying platforms (NFPs) and IoT. He has published more than 75 technical journal and conference papers and has contributed to 7 books, all in reputable venues. He is an editor of 2 research monographs and an author of a book entitled Green Heterogeneous Wireless Networks published jointly by Wiley and IEEE Press. He has been/is serving as a Chair/Co-Chair/Member of several workshops/special sessions and technical program committee of different IEEE flagship conferences, including Globecom, ICC, VTC and WCNC. He is an Associate Technical Editor of IEEE Communications Magazine and has served as a lead Guest Editor/Guest Editor for IEEE Communications Magazine, IEEE Wireless Communications and IEEE Access. He is serving as a Chair of IEEE ComSoc emerging technical committee on backhaul/fronthaul networking and communications. He is a Senior Member of IEEE, an active member of IEEE ComSoc and IEEE Standard Association.

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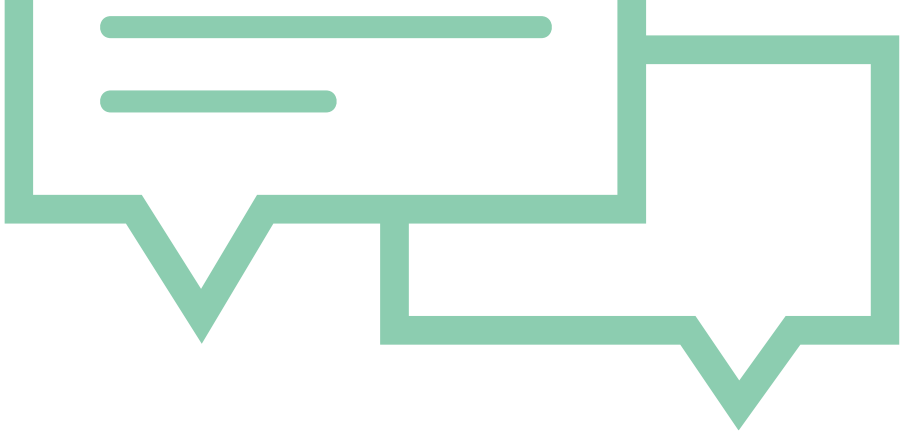
He has led a number of multimillion-funded international research projects encompassing the areas of energy efficiency, fundamental performance limits, sensor networks and self-organising cellular networks. He also led the new physical layer work area for 5G innovation centre at Surrey. He has a global collaborative research network spanning both academia and key industrial players in the field of wireless communications. He has supervised 20+ successful PhD graduates and published over 200 peer-reviewed research papers including more than 20 IEEE Transaction papers. He secured first rank in his B.Sc. and a distinction in his M.Sc. degree along with an award of excellence in recognition of his academic achievements conferred by the President of Pakistan. He has been awarded IEEE Comsoc's Fred Ellersick award 2014, FEPS Learning and Teaching award 2014, Sentinel of Science Award 2016, and twice nominated for Tony Jean's Inspirational Teaching award. He is a shortlisted finalist for The Wharton-QS Stars Awards 2014 for innovative teaching and VC's learning and teaching award in University of Surrey. He is a senior member of IEEE and a Senior Fellow of Higher Education Academy (SFHEA), UK.



CALL FOR CONTRIBUTIONS

ETI-BNC blog is intended for the research and industrial community to highlight key advancements in the area of backhaul and fronthaul communication networks. To this end, we encourage community members to contribute to the future blogs. We will accept contributions in following formats:

Review Articles: Review articles should highlight key issues relevant to fronthaul and backhaul communication networks. The articles should not exceed more than 3000 words and should have a maximum of 5 figures.
Position Papers: Position papers which highlight transformative new avenues for research are highly encouraged. These should not exceed 2000 word limit with a maximum of 3 figures.
News Items: News updates from industry and academia within the scope of BNC are welcome. News Items should be restricted to 500 words with a maximum of 1 image.
Call for Papers: Call for papers, book chapters and other contributions are also welcome. They should be within the scope of BNC and should not exceed one page.

Contributors are highly encouraged to get in touch with the editors.