Scopus

Documents

Ramli, H.A.M., Hashim, A.H.A., Asnawi, A.L.

Effective scheduling mechanism for a mixture of 5G multimedia use cases
(2023) *Computers and Electrical Engineering*, 108, art. no. 108701, .

Department of Electrical and Computer Engineering, International Islamic University, Malaysia

Abstract
This paper proposes a novel mechanism to address the challenging scheduling problem which is to maximize the ultra-Reliable Low Latency Communication (uRLLC) and enhanced Mobile Broad Band (eMBB) capacity at the desired Quality of Service (QoS) in the downlink Fifth Generation (5G) network. Though some packet scheduling mechanisms that can maximize the network capacity at the desired QoS are available, they were developed for before 5G mobile communication networks. These mechanisms may not perform well in the unique 5G framework that holds distinct characteristics. Conversely, the available 5G packet scheduling mechanisms were mostly developed to maximize capacity when the network contains only one 5G multimedia use case, assumed an ideal simulation environment in the performance evaluation, considered the legacy fixed numerology of 1 ms slot length and make use of mathematical analysis to maximize the desired metrics. Extensive performance evaluations conducted via computer simulations suggest the effectiveness of the proposed mechanism. At the desired uRLLC QoS which is Packet Error Rate (PER) at 10^{-5} threshold, the proposed mechanism maximizes the network capacity by 52.5% over a benchmark mechanism known as Virtual Token Modified-Largest Weighted Delay First (VTM) when an equal distribution of uRLLC and eMBB users are available. © 2023 Elsevier Ltd

Author Keywords
5G multimedia; Packet scheduling; Quality of service (QoS); Wireless network

Index Keywords
5G mobile communication systems, Packet networks, Scheduling algorithms, Wireless networks; 5g multimedium, Broad bands, Low-latency communication, Network Capacity, Packet scheduling, Performances evaluation, Quality of service, Quality-of-service, Scheduling mechanism, Scheduling problem; Quality of service

References

- **IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond**
(2015) *Rec. ITU-R M.2083-0*,

- Abdalkafor, A.S., Ali Alheeti, K.M.
A hybrid approach for scheduling applications in cloud computing environment
(2020) *Int J Electr Comput Eng*, 10 (2), pp. 1387-1397.

- Abdelbari, A., Haci, H.
An opportunistic user scheduling scheme for ultra-dense wireless networks
(2019) *ELECO 2019 - 11th International Conference on Electrical and Electronics Engineering, (February 2020)*, pp. 1080-1084.

- Abreu, R.B., Pocovi, G., Jacobsen, T.H., Centenaro, M., Pedersen, K.I., Kolding, T.E.
Scheduling enhancements and performance evaluation of downlink 5 G time-sensitive communications
(2020) *IEEE Access*, 8, pp. 128106-128115.

- Afroz, F., Sandrasegaran, K., Ghosal, P.
Performance analysis of PF, M-LWDF and EXP/PF packet scheduling algorithms in

3GPP LTE downlink
(2014) *2014 Australasian Telecommunication Networks and Applications Conference (ATNAC)*, pp. 87-92.

Aiyetoro, G., Takawira, F.
A cross-layer based packet scheduling scheme for multimedia traffic in satellite LTE networks
(2014) *IEEE 6th International Conference on New Technologies, Mobility and Security (NTMS)*, pp. 1-6.

Aiyetoro, G., Takawira, F.
A new user scheduling scheme in LTE/LTE-A networks using cross-layer design approach
(2015) *IEEE Military Communications Conference MILCOM*, pp. 1-6.

Akhtar, A., Arslan, H.
Downlink resource allocation and packet scheduling in multi-numerology wireless systems
(2018) *2018 IEEE Wireless Communications and Networking Conference Workshops, WCNCW 2018*, pp. 362-367.

Al-Ali, M., Yaacoub, E., Mohamed, A.
Dynamic resource allocation of eMBB-uRLLC traffic in 5 G new radio
(2020) *IEEE International Conference on Advanced Networks and Telecommunications Systems*, pp. 1-6.

Almekhlafi, M., Arfaoui, M.A., Elhattab, M., Assi, C., Ghrayeb, A.
Joint scheduling of eMBB and URLLC services in RIS-aided downlink cellular networks
(2021) *International Conference on Computer Communications and Networks (ICCCN)*, pp. 1-9.

Angri, I., Najid, A., Mahfoudi, M.
Performance evaluation of newly implemented resource blocks (RB) allocation schemes on NS-3 simulator for mMTC 5 G NR (New Radio) femtocells
(2020) *2020 5th International Conference on Cloud Computing and Artificial Intelligence: Technologies and Applications (CloudTech)*, pp. 1-8.

Basukala, R., Ramli, H.A.M., Sandrasegaran, K.
Performance analysis of EXP/PF and M-LWDF in downlink 3GPP LTE system
(2009) *2009 First Asian Himalayas International Conference on Internet*, pp. 1-5.

Chen, C., Huang, R., Baek, S.J., Yin, R., Yu, X., Li, C.
Channel-aware scheduling for coded packet broadcasting in full-duplex relay networks
(2022) *IEEE Wireless Communications and Networking Conference, WCNC, 2022-April*, pp. 1653-1658.

Dahlman, E., Parkvall, S., Skold, J., Beming, P., Al, E., Parkvall, S., Beming, P.
3 G Evolution: hspa and lte for mobile broadband
(2007), Elsevier Ltd

Demel, J., Bockelmann, C., Dekorsy, A.
Burst error analysis of scheduling algorithms for 5 G NR URLLC periodic deterministic communication
(2020) *2020 IEEE 91st Vehicular Technology Conference (VTC2020-Spring)*, pp. 1-6.

Eisen, M., Rashid, M.M., Ribeiro, A., Cavalcanti, D.
Scheduling low latency traffic for wireless control systems in 5 G Networks
(2020) *ICC 2020 - 2020 IEEE International Conference on Communications (ICC)*, pp. 1-6.

- Fitriasari, H.I., Lestari, A.I., Luhurkinanti, D.L., Sari, R.F.
Performance evaluation of downlink multi-user ofdma scheduling in 5 G new radio (NR)
(2021) *2021 18th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON)*, pp. 219-223.

- Husain, M.I., Haque, M.E., Tariq, F.
An efficient packet scheduling algorithm for uRLLC systems
(2020) *International Conference on UK-China Emerging Technologies (UCET)*, pp. 1-4.

- Iturralde, M., Yahiya, T.A., Wei, A., Beylot, A.-L.
Performance study of multimedia services using virtual token mechanism for resource allocation in LTE networks
(2011) *2011 IEEE Vehicular Technology Conference (VTC Fall*,

- Karimi, A., Pedersen, K.I., Mahmood, N.H., Pocovi, G., Mogensen, P.
Efficient low complexity packet scheduling algorithm for mixed URLLC and eMBB traffic in 5G
(2019) *IEEE Vehicular Technology Conference*, pp. 1-6.

- Kim, K., Koo, I., Sung, S., Kim, K.
Multiple QoS support using M-LWDF in OFDMA adaptive resource allocation
(2004) *IEEE Local and Metropolitan Area Networks Workshop(LANMAN)*, pp. 217-220.

- Krasilov, A., Lebedeva, I., Yusupov, R., Khorov, E.
Efficient Multiplexing of Downlink eMBB and URLLC Traffic with Massive MU-MIMO
(2022) *2022 IEEE International Black Sea Conference on Communications and Networking (BlackSeaCom)*, pp. 185-190.

- Li, P., Zhao, Y.B., Kang, Y.
Integrated channel-aware scheduling and packet-based predictive control for wireless cloud control systems
(2022) *IEEE Trans Cybern*, 52 (5), pp. 2735-2749.

- Maaz, D., Galindo-Serrano, A., Elayoubi, S.E.
URLLC user plane latency performance in new radio
(2018) *25th International Conference on Telecommunications (ICT)*, pp. 225-229.

- Manzoor, A., Kazmi, S.M.A., Pandey, S.R., Hong, C.S.
Contract-based scheduling of uRLLC packets in incumbent eMBB traffic
(2020) *IEEE Access*, 8, pp. 167516-167526.

- Mathew, A., Kumaran, K., Ramanan, K., Stolyar, A., Whiting, P.
Providing quality of service over a shared wireless link
(2001) *IEEE Commun*, 39 (2), pp. 150-154.

- Nasralla, M.M.
A hybrid downlink scheduling approach for multi-traffic classes in LTE wireless systems
(2020) *IEEE Access*, 8, pp. 82173-82186.

- Nasralla, M.M., Martini, M.G.
A downlink scheduling approach for balancing QoS in LTE wireless networks
(2013) *IEEE 24th Annual International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC)*, pp. 1571-1575.

- Panno, D., Riolo, S.
An enhanced joint scheduling scheme for GBR and non-GBR services in 5 G RAN
(2020) *Wireless Networks*, 26 (4), pp. 3033-3052.

- Panno, D., Riolo, S.
  An enhanced joint scheduling scheme for GBR and non-GBR services in 5 G RAN
  (2020) *Wireless Networks*, 26 (4), pp. 3033-3052.

- Patriciello, N., Lagen, S., Giupponi, L., Bojovic, B.
  5 G new radio numerologies and their impact on the end-to-end latency
  (2018) *IEEE 23rd International Workshop on Computer Aided Modeling and Design of Communication Links and Networks (CAMAD)*, pp. 1-6.

- Pedersen, K.I., Berardinelli, G., Frederiksen, F., Mogensen, P., Szufarska, A.
  A flexible 5 G frame structure design for frequency-division duplex cases
  (2016) *IEEE Commun Mag*, 54 (3), pp. 53-59.

- Pocovi, G.A., Pedersen, K.I., Soret, B., Lauridsen, M., Mogensen, P., Klaus, I., Mogensen, P.
  On the impact of multi-user traffic dynamics on low latency communications
  (2016) *Proceedings of the International Symposium on Wireless Communication Systems*, pp. 204-208.

- Pocovi, G., Pedersen, K.I., Mogensen, P.
  Joint link adaptation and scheduling for 5 G ultra-reliable low-latency communications
  (2018) *IEEE Access*, 6, pp. 28912-28922.

- Pocovi, G., Soret, B., Pedersen, K.I., Mogensen, P.
  MAC layer enhancements for ultra-reliable low-latency communications in cellular networks
  (2017) *IEEE International Conference on Communications Workshops*, pp. 1005-1010.

- Ramli, H.A.M., Isa, F.N.M.
  Improving real-time multimedia scheduling in practical mobile cellular channels
  (2016) *IEEE 6th International Conference on Intelligent and Advanced Systems (ICIAS)*, pp. 1-6.

- Ramli, H.A.M., Hashim, A.H.A., Rasied, T.S.M., Asnawi, A.L., Rahman, F.D.A.
  A Study of an Efficient Scheduling Algorithm for Simultaneous 5 G Multimedia Traffic
  (2022) *2022 International Conference on Computer and Drone Applications (IConDA)*, pp. 113-118.

- Ramli, H.A.M.
  A study on packet scheduling algorithms for healthcare contents over fifth generation 5 G) mobile cellular network
  (2020) *Int J Electr Telecommun*, 66 (4), pp. 729-735.

- Ramli, H.A.M., Isa, F.N.M., Asnawi, A.L., Jusoh, A.Z., Azman, A.W.
  Urgency-aware scheduling algorithm for downlink cognitive Long Term Evolution-Advanced
  (2019) *IEEE 89th Vehicular Technology Conference (VTC Spring)*, pp. 1-5.

- Ramli, H.A.M., Rizman, Z.I.
  Novel scheduling algorithm for optimizing real-time multimedia performance in Long Term Evolution-Advanced
  (2017) *Turk J Electr Eng Comput Scis*, 25 (1), pp. 247-273.

- Ramli, H.A.M., Sandrasegaran, K., Ismail, A.F., Latif, S.A., Isa, F.N.M.
  A simulation tool for downlink long term evolution-advanced
  (2014) *Res J Appl Scis, Eng Technol*, 8 (19), pp. 2032-2041.

- Rhee, J.-H., Holtzman, J.M., Kim, D.K.
  Scheduling of real/non-real time services: adaptive EXP/PF algorithm

(2003) *57th IEEE Semiannual Vehicular Technology Conference*, pp. 462-466.

• Rhee, J.-H., Holtzman, J.M., Kim, D.K.
Performance analysis of the adaptive EXP/PF channel scheduler in an AMC/TDM system
(2004) *IEEE Commun Lett*, 8, pp. 4978-4980.

• Sandrasegaran, K., Ramli, H.A.M., Basukala, R.
Delay-prioritized scheduling (DPS) for real time traffic in 3GPP LTE system
(2010) *IEEE Wireless Communication and Networking Conference*, pp. 1-5.

• Shakkotai, S., Stolyar, A.
A study of scheduling algorithms for a mixture of real- and non-real-time data in HDR
(2000) *Bell Labs Tech Memo*,

• Shi, B., Zheng, F.-C., She, C., Luo, J., Burr, A.G.
Risk-Resistant Resource Allocation for eMBB and URLLC Coexistence Under M/G/1 Queueing Model
(2022) *IEEE Trans Veh Technol*, 71 (6), pp. 6279-6290.

• Silva, G.M.F., Abrão, T.
Throughput and latency in the distributed Q-learning random access mMTC networks
(2022) *Comput Networks*, 206.

• Song, X., Yuan, M.
Performance analysis of one-way highway vehicular networks with dynamic multiplexing of eMBB and URLLC Traffics
(2019) *IEEE Access*, 7, pp. 118020-118029.

• Bag, T., Garg, S., Shaik, Z., Mitschele-Thiel, A.
Multi-numerology based resource allocation for reducing average scheduling latencies for 5 G NR wireless networks
(2019) *European Conference on Networks and Communications (EuCNC)*, pp. 597-602.

• (2004), Third Generation Partnership Project (3GPP). Feasibility study for Orthogonal Frequency Division Multiplexing (OFDM) for UTRAN enhancement (Release 6), TR25.892, version 6.0.0.

• **Study on physical layer enhancements for NR ultra-reliable and low latency case (URLLC) (Release 16)**
(2019) *TR 38.824 V16.0.0 (2019-03)*,

• (2021), Third Generation Partnership Project (3GPP). Technical specification group services and system aspects; system architecture for the 5 G system (5GS); Stage 2, (Release 17), TS 23.501 V17.2.0 (2021-09).

• Wang, J., Wang, Y., Wang, S.
A dynamic resource allocation scheme based on cognition in LTE system
(2019) *Int J Wireless Mobile Comput*, 16 (4), pp. 281-289.

• Wang, Q., He, C., Jaffres-Runser, K., Huang, J., Xu, Y.
Timely-throughput optimal scheduling for wireless flows with deep reinforcement learning
(2022) *2022 IEEE/ACM 30th International Symposium on Quality of Service (IWQoS*, pp. 1-11.

• Yu, C., Chen, S., Wang, F., Wei, Z.
Improving 4 G/5 G air interface security: a survey of existing attacks on different

LTE layers
(2021) *Comput Networks*, 201.

- Zegallai, H.M., Awad, S.A.
Packet scheduling with carrier aggregation for balancing QoS in LTE advanced Networks
(2021) *2021 IEEE 1st International Maghreb Meeting of the Conference on Sciences and Techniques of Automatic Control and Computer Engineering MI-STA*, pp. 882-886.

- Zhang, C.C., Nguyen, K.K., Cheriet, M.
Joint Routing and Packet Scheduling For URLLC and eMBB traffic in 5 G O-RAN
(2022) *ICC 2022 - IEEE International Conference on Communications*, pp. 1900-1905.

Correspondence Address
Ramli H.A.M.P.O.Box 10, Malaysia; email: hadibahmr@iium.edu.my