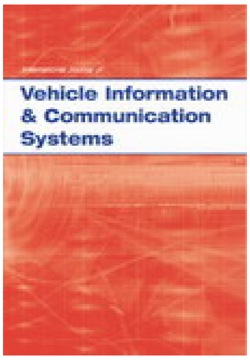


International Journal of Vehicle Information and Communication Systems

ISSN online: 1741-8208 - ISSN print: 1471-0242
https://www.inderscience.com/ijvics

Real-time load balancing and dynamic profile management in mobile data networks

Ajay Dureja, Aman Dureja, Suman, Payal Pahwa

DOI: 10.1504/IJVICS.2023.10057066

Article History:

Received:	01 November 2022
Last revised:	04 January 2023
Accepted:	29 January 2023
Published online:	20 June 2023

Real-time load balancing and dynamic profile management in mobile data networks

Ajay Dureja*

Department of Information Technology,
Bharati Vidyapeeth's College of Engineering,
Paschim Vihar, Delhi, India
Email: ajaydureja@gmail.com
*Corresponding author

Aman Dureja

Department of Information Technology,
Bhagwan Parshuram Institute of Technology,
Sector-17, Rohini, Delhi, India
Email: amandureja@gmail.com

Suman

Department of Computer Science & Engineering,
Deenbandhu Chhotu Ram University of Science and Technology,
Murthal, Haryana, India
Email: suman.cse@dcrustm.org

Payal Pahwa

Department of Computer Science & Engineering,
Bhagwan Parshuram Institute of Technology,
Sector-17, Rohini, Delhi, India
Email: pahwapayal@gmail.com

Abstract: As mobile data grows rapidly, carriers must intelligently manage network traffic. Due to economic realities and the physical limitations of the available spectrum, operators cannot add more network capacity. To satisfy investors, operators must maximise their service returns. The more services a subscriber receives, which costs more, the higher their expectations of acceptable network availability and quality. So it becomes very challenging for operators to provide QoS to their high-value subscribers and manage network traffic dynamically without impacting the user experience of their potential and key users. In this paper, all literature surveys are carried out on different schemes and solutions to manage mobile data networks' profiles. This paper aims to identify an effective way of managing real-time data traffic by adjusting QoS/profile parameters dynamically so that high-value subscribers get better QoS during congestion than regular users.

Keywords: quality of service; quality of experience; dynamic profile management; HVC.

Reference to this paper should be made as follows: Dureja, A., Dureja, A., Suman and Pahwa, P. (2023) 'Real-time load balancing and dynamic profile management in mobile data networks', *Int. J. Vehicle Information and Communication Systems*, Vol. 8, Nos. 1/2, pp.33–49.

Biographical notes: Ajay Dureja is currently working as Assistant Professor in Department of IT at Bharati Vidyapeeth's College of Engineering, New Delhi. He did his PhD (CSE) from Deenbandhu Chhotu Ram University of Science and Technology, Murthal (Haryana) India. He qualified his Master's in Technology ('A' Grade) in Computer Engineering Specialisation in 2010 from M.D. University. He is credited with 15 years of teaching, research, and administrative experience in premier technical Institutions in India. He is certified trainer of SAP ABAP from SAP India Pvt. Ltd. and certified in CCNA from Cisco Networking Academy, India. His research areas are internet of vehicles, internet of things, MANETs, wireless networks, and image processing.

Aman Dureja is currently working as Assistant Professor in Department IT at Bhagwan Parshuram Institute of Technology, Rohini, New Delhi. He did his PhD (CSE) from Guru Gobind Singh Indraprastha University, Delhi. He did his MTech in Computer Engineering in 2010 from M.D. University. He presently has over 15.3 years of teaching experience. He is certified trainer of SAP ABAP from SAP India Pvt. Ltd. and certified CCNA Trainer from Cisco Networking Academy, India. His research interests are in the areas of image processing, computer vision, machine learning and deep learning. Eight students have been awarded MTech degrees under his supervision.

Suman has been into teaching and research for about 20 years. She did her PhD from Deenbandhu Chhotu Ram University of Science and Technology, Murthal (Haryana), India. Her areas of expertise include internet of things (IoT), wireless sensor networks, mobile ad-hoc networks. She received her MTech degree in Computer Science & Engineering from Kurukshetra University, Kurukshetra, India. She has published more than 60 papers in various journals and conferences of repute.

Payal Pahwa is Principal in Bhagwan Parshuram Institute of Technology. She has a teaching and administrative experience of 26 years. There are more than 60 international research publications to her credit. Her areas of research include big data and data mining. She is currently guiding five research scholars in these areas.

1 Introduction

1.1 Mobile data network

During peak hours, network traffic increases, resulting in congestion and affecting User's Quality of Service (Li et al., 2012). It is necessary to provide High Quality of Service through the networks. It is expected by networks to provide High Quality of Service at any cost. But the latest hardware and over-provisioning networks are not feasible to provide such quality of service. As network resources are expensive, limited, and shared with many users simultaneously, an improved end user quality of services can be obtained in three ways: firstly by cost-effective consumption of network assets, secondly by adapting bandwidth distribution, and finally by user profile management with dynamism.

One can simulate the network traffic congestion problem (Almatar, 2022) with road transport traffic congestion problem. Public roads have fixed widths, and during peak hours, they get congested with vehicle traffic. However, it must divert or block traffic to quick transit of some particular or VIP's vehicle such as Ambulance, Fire Brigade, red beacon lights of Ministers/officials, etc. These special/VIP vehicles can then transit smoothly and quickly compared to other normal vehicles. The same concept can bring in mobile broadband networks by applying dynamic profile management, which manages user profiles dynamically during congestion and provides better QoS to high-value or VIP users compared to regular users. Figure 1 shows different traffic scenarios in different situations.

Figure 1 Different traffic scenarios in different conditions

Scenario 1: Different Lane for special vehicles

Scenario 2: Block of traffic for special vehicle ambulance

Scenario 3: Traffic congestion with no management

1.2 Dynamic profile management

It can play a major role in enhancing the Quality of Services in mobile data networks. In this technique, when congestion appears in the network, users' profile will get dynamically managed (Chinewar and Manusmare, 2016). Two terms are associated with services related to mobile data networks. One is quality of experience (QoE), and the second is Quality of Service (QoS) (Ixia, 2013). QoE describes the user perceptions related to the performance of a service and QoS describes the network's ability to give a certain service level. To achieve the best QoE in a competitive, efficient, and cost-effective manner, network providers and service providers must effectively manage network QoS.

The paper is divided into sections: Section 1 presents a brief introduction of Mobile Data Network and Dynamic Profile Management. Related work on service quality for the users, load balancing, traffic control and avoidance is outlined in Section 2. Comparison of different traffic load balancing techniques with possible resolutions is described and tabulated in Section 3. Section 4 presents experimental results. Section 5 presents the conclusion and future work of this paper.

2 Literature review

Network congestion during peak hours is a severe problem that should be addressed by all users nowadays owing to the increasing use of smartphones and data usage worldwide. The user's concern is to provide better Service Quality (QoS) to their end users. Much research has been done in the past regarding load balancing, traffic control, traffic control and avoidance.

Truina and Furuskar (2005) discussed on GSM-WCDMA networks and focused on how the best WCDMA & GSM works for the network. Authors also found that delivery between 2G and 3G networks requires effective means of traffic control and support for service continuity during system switching. This paper addresses capacity gain by combining the advantages of GSM & WCDMA techniques (Truina and Furuskar, 2005). The proposed system's main weakness is that it is not capable of handling multilayer systems like multiband UMTS networks.

Bandara et al. (2005) demonstrate applications of policy refinement to the management of DiffServ QoS. Authors demonstrated how policies can be filtered and which tool support can be provided through the filtering process using examples from the QoS management domain. They applied the diffServ QOS to match the algo using Goal Elaboration & Abductive reasoning. The main advantage of the proposed approach is that it can also be used for storage area networks or security management.

Klein et al. (2011) compares various load-balancing methods in their execution. The author discussed three load consideration methods: antenna to normalisation, supply parameter adjustment and cell disruption communication. Imitation results have shown that the techniques used are consistent, the Handover parameter variation and the motion of the moving antenna are effective for overloaded cells in medium and low load areas, though cell disruption interactions meaningfully improve effectiveness, particularly at high load areas (Klein et al., 2011). The proposed technique does not address the solution for high dynamic network. To overcome this kind of issue, we have proposed a technique for dynamic profile management.

Munoz et al. (2011) worked on an inexpensive solution to increase network capacity. Author focused on proper configuration of the supply parameters to determine the load balance on the GERAN. Researchers have developed the Fuzzy Logic Controller, which greatly reduces call barriers and provides better performance and usability. Improved logic was tested with MATLAB using the Fuzzy Q Learning algorithm (Munoz et al., 2011). Capdevielle et al. (2011) face the challenge of sharing the spectrum of LTE Pico cell networks (PC) with various traffic loads and improved resource-sharing strategies.

Apps are selected and updated by each PC individually. The need was to improve all outputs and responses to real traffic needs.

Lei et al. (2011) investigated the balance of load between TD-SCDMA systems which is different from GSM with asymmetric traffics. They analysed the handoff performance status, the amount of traffic transported, and the conditions for choosing clients to be transported in every case (Radojevic and Žagar, 2011; Lei et al., 2011).

Li et al. (2011) investigate load reduction and balancing of 3GPP networks (multicell). First, the issue was divided into a multi-task problem, and then solving each task the complete solution and the complexity of the proposed work solution were analysed. Subsequently, an effective and low-cost algorithm, Network Load Reduction with a Load Balance Algorithm (NLMLB), was proposed to combine the decision-making process with the call-acceptance process. Imitation results have shown that the proposed algorithm can reduce call barriers, decrease system service performance, and improve network system bandwidth (Li et al., 2011). Table 1 shows comparison of different traffic load balancing techniques with possible solutions.

The existing network infrastructure uses static-type switches. As a consequence, poor utilisation of network resources. It is the main issue in dynamic profile management & load balancing in mobile data networks. Vishwakarma and Pavithra (2022) implemented various load-balancing algorithms to resolve this issue In their research work, authors implemented various load balancing algorithms for SDN based Data Centre network and compared their results.

Sivagar and Prabakaran (2021), in their proposed work, devised a mechanism using an Advanced Real-Coded Genetic Algorithm (DLBM-ARGA) for dynamic profile management. The proposed algorithm mainly focuses on ideal base station and coverage configuration.

In 2020, Attiah et al. presented a reinforcement learning framework for optimising neighbour cell parameters by which the traffic of different cells can be better balanced. These different cells are part of the geographical cluster. The authors also presented a design of the learning framework that includes key system performance indicators. Hence, proposed a new framework for load balancing (Attiah et al., 2020) in between different cells of the cluster.

Zakia and Ben Yedder (2017) proposed SDN-based dynamic load management algorithm for optimising link utilisation in DCNs. The proposed algorithm finds the shortest paths from each host to others and calculates every link's cost. It replaces the previous path with best path when it encounters a congestion in its current path.

3 Real time load balancing and dynamic profile management in mobile data networks

This paper deals with providing a better Quality of Services and Quality of Experience to the high-value subscriber where there is congestion in the network. The proposed method focuses on improving QoS (Soldani et al., 2006) for end users by adjusting the network bandwidth and managing the user profile dynamically. The proposed solution shows how congestion affects the Quality of Experience, use of policy management, and common Quality of Service (QoS) by the operators and alleviates high-level service quality and network congestion.

Table 1 Comparison of different traffic load balancing techniques with possible resolutions

S. No	*Paper Name*	*Year*	*Author*	*Worked On*	*Tools Used*	*Algorithm*	*Conclusion*	*Future Work*
1	Force-based Load Balancing in co-located UMTS/GSM Networks	2004	Andreas Pillekeit, Fariborz Derakhshan, Enrico Jugl, Andreas Mitschele-Thiel	1 Focused on Intelligent algorithms that decide the load balancing between the different radio technologies. 2 Algorithms used, is based on the approach previously employed to balance the load of distributed computing systems. 3 Study of algorithm has been done for optimum assignment of mobiles to a radio technology during call setup as well as during the call.	Simulation Tools for the Evaluation of Algorithm in Mobile Networks (STEAM)	Force Based CRRM Algorithm	1 Overall capacity and the provide QoS could be vastly improved in the case of overload situations. 2 The algorithms also proved very robust with respect to changes of the parameters. 3 Connected Mode based Solution. But a decentralised solution. 4 Nice simplification of problem. 5 Candidate based solution. 6 One way UMTS-GSM HOs as GSM call are unlikely to support UMTS. 7 Algorithm to prevent Ping-Pongs.	1 Application of the CRRM algorithm to packet-switched traffic. 2 Extension of the algorithms to handle more complex multilayer systems including multiband UMTS networks.
2	Traffic Steering and Service Continuity in GSM-WCDMA Seamless networks	2005	D. Truina, A. Furuskar	1 Focused on how best GSM & WCDMA take advantage of each other. 2 Handover between 2G & 3G networks required efficient mechanisms for traffic management between then and support for service continuity at the time of system changeover.	Load Balance Tool (by Ericsson)	Capacity Modelling Algorithm	1 Need of Traffic Steering and Service continuity mechanism to introduce WCDMA along with GSM 2 Inter-system Changes to be kept to a minimum so that the performance could be maximise 3 Targeted voice service for service continuity by providing efficient traffic steering mechanism and Introduce load balancing solutions based on voice 4 Avoids inter-RAT HD due to long service disruption 5 Idle mode centric	1 In Long Run, Penetration of WCDMA Increases, hence it may requires to address traffic-steering and service-continuity mechanisms for packet data services. 2 How to distribute load from subscribers in idle mode.

Table 1 Comparison of different traffic load balancing techniques with possible resolutions (continued)

S. No	*Paper Name*	*Year*	*Author*	*Worked On*	*Tools Used*	*Algorithm*	*Conclusion*	*Future Work*
3	Policy Refinement for DiffServ Quality of Services Management	2005	A. Bandara, E. Lupu, A. Russo, N. Dulay, M. Sloman, P. Flegkas, M. Charalambides, G. Pavlou	1 This paper shows how to apply Policy refinement to the domain of DiffServ QoS management. 2 This paper shows how policy can be refined and what tool support can be provided for the refinement process using examples from QoS management domain.	NA	Goal Elaboration & Abductive reasoning	By using goal elaboration and abductive reasoning strategies with event and constraint, it shows how policies can be refined	Further study is supposed to do on analysis capabilities to evaluate the consistency of the results
4	The Simulations of static Load Balancing Algorithms	2009	Hendra Rahmawan, Yudi Satria Gondokaryono	1 Four static load balancing algorithms are simulated, and their performance are compared. 2 CPU, Memory and hard disk I/O are the load indices used.	Discrete event simulator	Round Robin, Randomised, Central Manager, and Threshold	1 Central Manager algorithm is the best static load balancing algorithm that gives fastest execution time. 2 Central Manager and Threshold algorithm both are the two best static load balancing algorithms that able to balance loads well. 3 A good simulation made example. 4 No performance penalties for HO.	1 To simulate other load balancing algorithm. 2 To evaluate performance on parameters other than execution time and workload distribution. 3 To simulate for heterogeneous system.

Table 1 Comparison of different traffic load balancing techniques with possible resolutions (continued)

S. No	*Paper Name*	*Year*	*Author*	*Worked On*	*Tools Used*	*Algorithm*	*Conclusion*	*Future Work*
5	Analysis of Issues with Load Balancing Algorithms in Hosted (Cloud) Environments	2010	Branko Radojevic, Marion Zagar	1 Analysis of detected issues with load balancing algorithms in Hosted environments. 2 The new algorithm incorporates information form. 3 Virtualised computer environments and end user. 4 Experience in order to be able to proactively influence load balancing decisions or reactively change decision in handling critical situations.	NA	Round Robin Algorithm	Bad/poor Load balancing models and algorithm that can dynamically adapt to situations on servers to which they actually forward traffic.	Further development of this model is the field ware future research will be conducted.
6	Traffic Load Balance Methods in the LTE-Advanced System with Carrier Aggregation	2010	Lei Zhang, Fei Liu, Lin Huang and Wenbo Wang	1 Two traffic load balance methods are proposed to improve the performance of the independent carrier scheduling (ICS) scheme in carrier aggregation based LTE-advanced system with time-variant user population. 2 One is to utilise advanced user allocation rules. 3 The other is a novel method which couples the component carriers (CCs) together in the scenario that the CCs are in the different working states.	NA	1 Joint carrier scheduling scheme (JCS). 2 Independent Carrier Scheduling (ICS). 3 Advanced User Allocation Rules	1 Simulation results showed that well designed user allocation rules can achieve better traffic load balance across the CCs than the simplest random allocation rule. 2 The CC coupling method can make the ICS scheme achieve optimal performance as the joint carrier scheduling (JCS) scheme, irrespective of the traffic intensity and the used user allocation rule. 3 JSQ is the most efficient user allocation rule to balance the traffic load across the ICS can perform close the JCS by using JSQ when the traffic intensity is very heavy.	NA

Table 1 Comparison of different traffic load balancing techniques with possible resolutions (continued)

S. No	*Paper Name*	*Year*	*Author*	*Worked On*	*Tools Used*	*Algorithm*	*Conclusion*	*Future Work*
7	Optimisations of a Fuzzy Logic Controller for Handover-based Load Balancing	2011	P. Mu'noz, R. Barco, I. de la Bandera, M. Toril and S. Luna-Ram'irez	1 Fine tuning of Handover parameters to achieve cell load balance in GSM-EDGE Radio Access Network (GERAN). 2 Fuzzy Logic Controller (FLC) providers good performance and usability	MATLAB	FUZZY Q Learning algorithm	1 Optimised FLC provinces a significant reduction in call blocking. 2 Cost effective solution to increase network capacity.	How to control call drops which get incremented due to this solution. How to control network signalling load due to a higher number of Handovers
8	Enhanced Resource Sharing Strategies for LTE Pico cells with Heterogeneous Traffic Loads	2011	Veronique Capdevielle, Afef Feki and Elias Temer	1 This paper addresses the problem of spectrum sharing for LTE pico cells (PCs) networks with heterogeneous traffic loads. 2 Design of Distributed mechanisms to steer PCs to select most suitable resources. 3 To maximise overall Throughput. 4 To responds to the real traffic needs.	3D ray tracing tool	Dynamic Cooperative Algorithms (DCA) & Dynamic Non-cooperative Algorithms (DNCA)	1 Innovative approach for spectrum sharing. 2 Resources are selected and updated by each PC in an autonomous way. 3 Create and objective function using queuing theory Cost function. 4 Optimised solution that optimises the overall throughput.	How to reuse self-adaptive spectrum through an increasing/decreasing spectrum allocation mechanism that dynamically adjusts the selected resource to the real needs.
9	Load Balancing between TD-SCDMA and GSM Systems with Asymmetric Traffics	2011	Liang Leil, Aiping Haung, Cunqing Hua, Zhouyun Wu, Jun Qian, Liang Shen, Xinwei Chen, Yusheng Zhang	1 This paper investigated load balancing between heterogeneous TD-SCDMA and GSM systems with asymmetric traffics. 2 Analysis has been done on trigger condition of hand-off operation, the traffic volume to be migrated and the criteria of selecting users to be migrated for each case.	NA	Handoff balancing algorithm	1 This load balancing can make the load gap of the concerned link smaller, and the performance of the higher-load system has improved efficiently. 2 When and how to move UE via inter-RAT. 3 User Priority & Selection.	NA

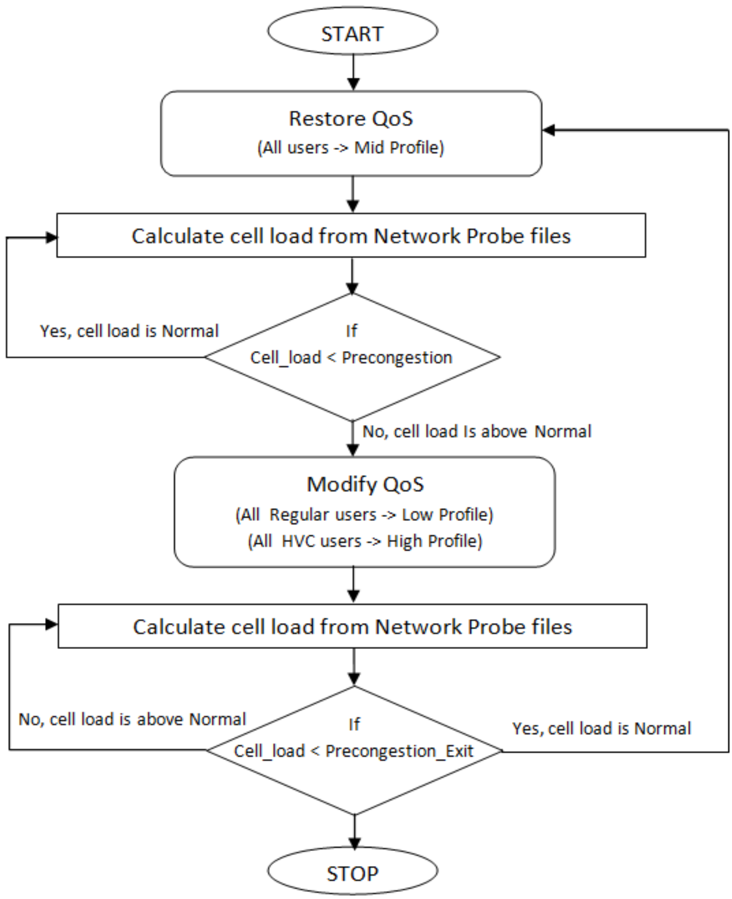
Table 1 Comparison of different traffic load balancing techniques with possible resolutions (continued)

S. No	Paper Name	Year	Author	Worked On	Tools Used	Algorithm	Conclusion	Future Work
10	Joint Optimisation on Load Balancing and Network Load in 3GPP LTE Multi-cell Networks	2011	Zhihang Li, Hao Wang, Zhiwen Pan, Nan Liu and Xiaohu You	1 This paper investigated load balancing and network load minimisation in 3GPP LTE mutli-cell networks. 2 Firstly, the problem was formulated to be a multi-optimisation problem, then complexity and overhead of the optimal solution of the problem had been analysed. 3 After that, a practical and low- overhead algorithm, NLMLB was proposed which includes a handover decision process and a call admission control process.	NA	Network Load Minimisation with Load Balancing algorithm (NLMLB)	Simulation results showed that NLMLB algorithm can effectively decrease the new call blocking rate, reduce network resource occupation and increase the network bandwidth efficiency.	NA
11	Potential of intra LTE, intra-frequency load balancing	2011	Siegfried Klein, Ingo Karla, Edgar Kuehn	1 This paper compares different load balancing mechanisms and their combinations in respect to their performance. 2 The investigation focuses on three load balancing mechanisms: handover parameter adaptation, antenna tilt adaptation and inter cell interference coordination.	Downlink Simulator	NA	Simulation results showed that used techniques are complementary, Handover parameter variations and antenna tilt adaptation excel for overloaded cells in low and medium load environments, while inter cell interference coordination significantly improves the performance especially in high load environments.	NA

Quality of Service management aims to satisfy the Service Level Agreements (SLAs) contracted by the provider. Dynamic Profile management will play a fundamental role in implementing QoS in mobile broadband.

The solution depends on network probe file data, providing cell load information at regular intervals. Figure 2 represents the flowchart for the proposed solution. The algorithm for the proposed solution is given below.

Figure 2 Flowchart for the proposed solution



3.1 Algorithm

- By default all users are in MID profile.
- When Cell is in Pre-Congestion State, it needs to modify QoS and all HVC users are moved to HIGH profile and REGULAR users are moved to LOW profile.
- When Cell state is normal from Pre-Congestion, all HVC and REGULAR customers are restored to MID Profile.

4 Experiment results

4.1 System assumptions

To simplify the simulation system, some assumptions are made:

(a) Availability of Network traffic logs (e.g. Traffic Logs/RNC Logs)

(b) Availability of High-Value Customer (HVC) Information

(c) Subscriber (under monitoring) data in the same monitoring cell (area) through IPERF or any available tool.

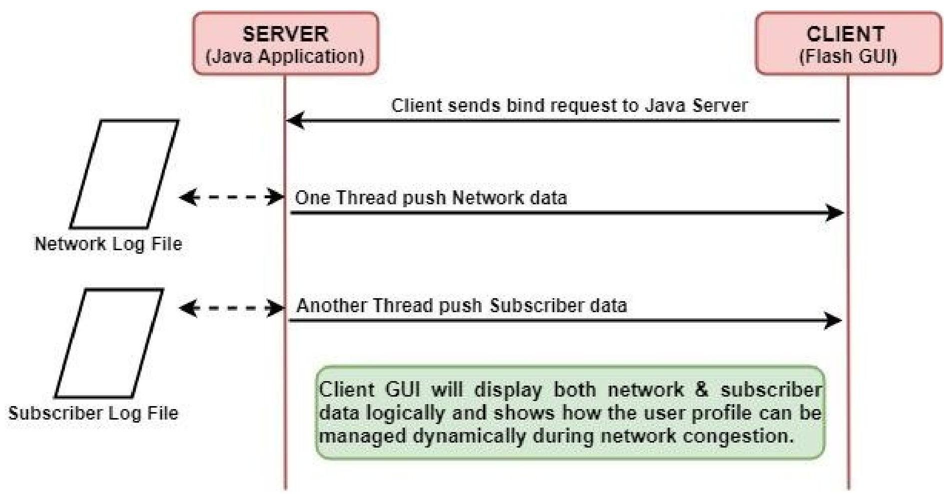
4.2 General setup of simulations

The simulation has done using the client-server architecture by using java application as server and flex AIR application as client. Client sends bind (socket) request to Java server, receives network and subscriber data through socket pipe, and displays the impact of dynamic profile management.

4.3 Simulation design

Figure 3 shows the simulation design.

Figure 3 Simulation design



4.4 Simulation algorithm

Step 1: Java Application (server) on execution, waits for the client application to bind the socket connection at the defined port.

Step 2: Client (GUI Application), once started, will send the bind request to Java Application (server).

Step 3: Once the socket gets established, Java server will then push data (XML String) to client GUI. There will be two threads executing in parallel.

Step 4: One thread will push network data (including cell id, cell congestion, threshold, all subscriber details).

Step 5: Another thread will push subscriber data that are under investigation.

Step 6: Client GUI will display the network and subscriber behaviour as per following:

- As per Network Behaviour
  - It display all users belongs to cell. (circle user will denotes normal user whereas star user will denotes HVC).
  - Display current cell load/utilisation.
  - Line chart to display all subscriber's current throughput.
  - Grid table to display all subscriber details along with their current profile.
  - DPM Policy table that display the current cell state (if congested, pre-congested or normal), DPM ON/OFF, ENTRY/EXIT Threshold etc.
- As per Subscriber Behaviour
  - It display IPERF users that are under investigation.
  - Display User's throughput, packet loss and RTT.

Step 7: On detection of congestion, the cell state colour in DPM Policy table changes to red and needful action will be taken as per DPM design flow (Figure 8).

Figure 4 Java application (server) waiting for the client application to bind the socket connection

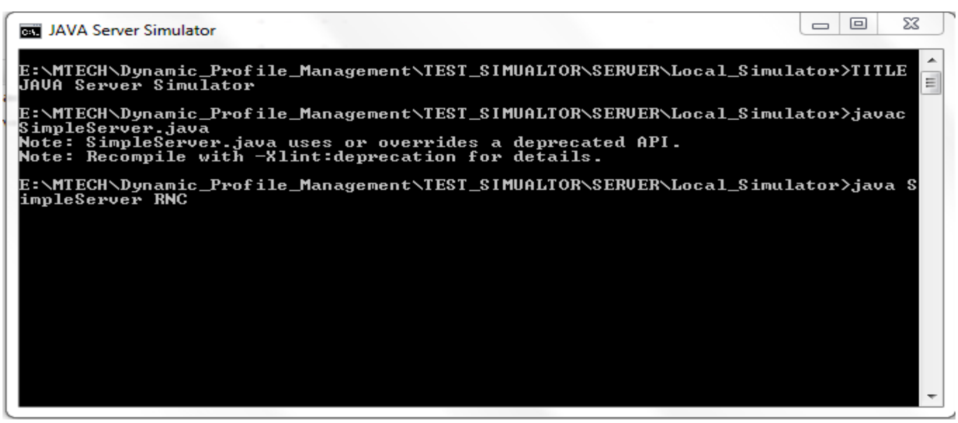


Figure 5 Bind request to Java application (server)

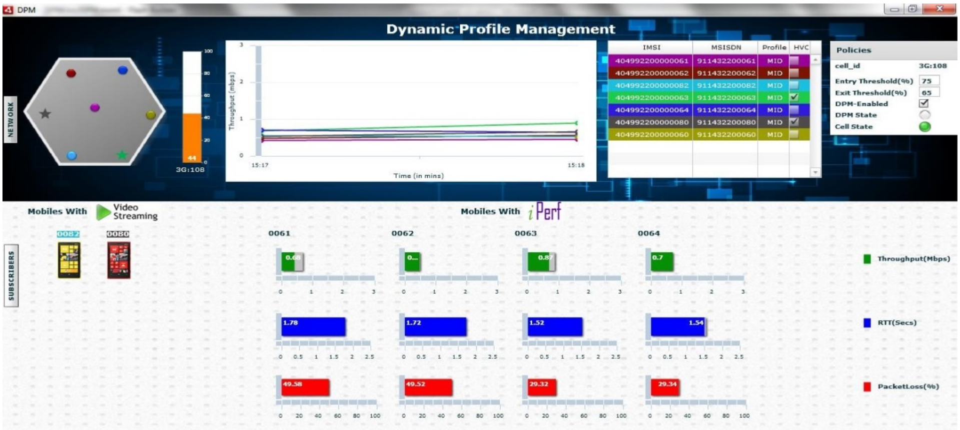


Figure 6 Dynamic profile management

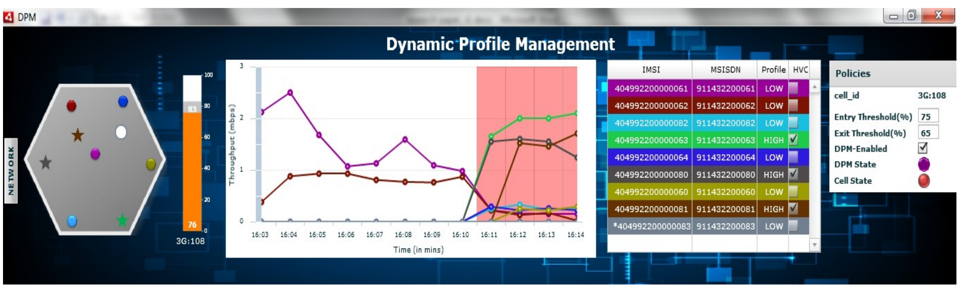


Figure 7 Dynamic profile management as per subscriber behaviour

Figure 8 On detection of congestion, the cell state colour in DPM policy

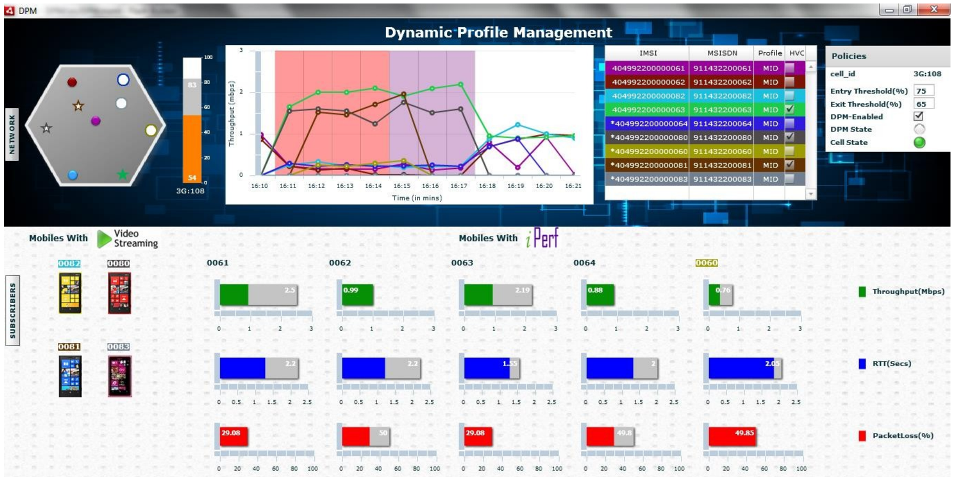
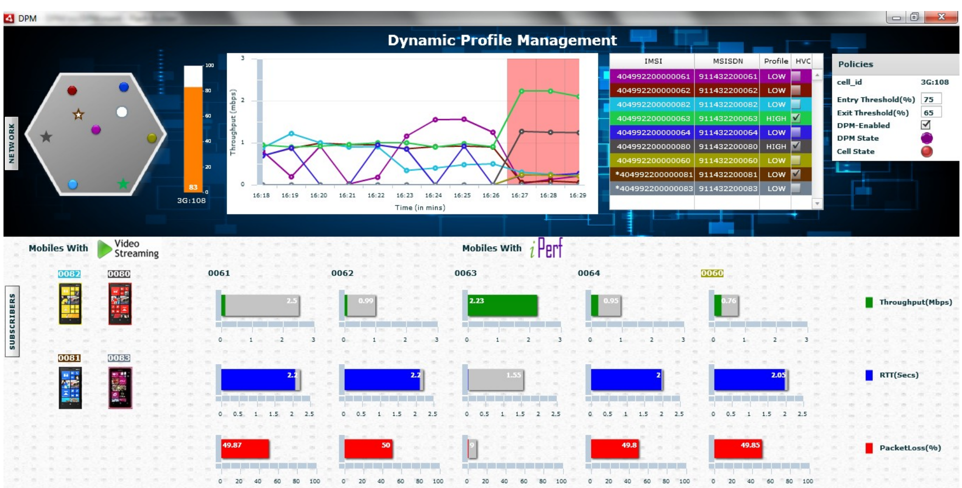


Figure 9 shows the action taken by DPM as per DPM design flow. It shows an efficient profile management mechanism during traffic congestion detection. The proposed technique is much better than the technique implemented in Song et al. (2007) in load balancing and profile management in terms of throughput, packet loss and RTT. High utilisation is achievable by dynamically balancing the offered traffic load. By applying the proposed technique, significant performance improvement is observed.

Figure 9 Action taken by DPM as per DPM design flow



5 Conclusion

During network congestion, provision can be made at network level to provide best quality of service to High Value Customers (HVC) by restoring their QOS profile to High. Normal/Regular users will get impacted during congestion, and their QOS profile is also restored to Low. By adapting network bandwidth and managing user profile dynamically, the end-user network Quality of Services can be improved.

5.1 Future work

In this paper, the focus was more on QoS for a particular subscription and service type also. Our work only targeted managing policy dynamically during congestion, benefiting only HVC users. Alternates could be explored to provide benefits to normal users during the congestion. Avoiding network congestion or load balancing also the user efficiency features on which more work can be done from a future perspective. Also, big data problem will be the growing/biggest concern to address in future work.

References

Almatar, K.M. (2022) 'Traffic congestion patterns in the urban road network: (Dammam metropolitan area)', *Ain Shams Eng. J.*, p.101886. DOI:https://doi.org/10.1016/j.asej.2022.101886.

Attiah, K., Banawan, K., Gaber, A., Elezabi, A., Seddik, K., Gadallah, Y. and Abdullah, K. (2020) 'Load balancing in cellular networks: a reinforcement learning approach', *IEEE 17th Annual Consumer Communications & Networking Conference (CCNC)*, pp.1–6. DOI:10.1109/CCNC46108.2020.9045699.

Bandara, A., Lupu, E., Russo, A., Dulay, N., Sloman, M., Flegkas, P., Charalambides, M. and Pavlou, G. (2005) 'Policy refinement for diffserv quality of services management', *Integrated Network Management*, *9th IFIP/IEEE International Symposium on*, 15–19 May, pp.469–482.

Capdevielle, V., Feki, A. and Temer, E. (2011) 'Enhanced resource sharing strategies for LTE picocells with heterogeneous traffic loads', *Vehicular Technology Conference*, Budapest, 15–18 May, pp.1–5.

Chinewar, P.D. and Manusmare, A. (2016) 'Dynamic profile management using network traffic parameters', *International Journal of Science and Research*, Vol. 5, No. 8, pp.653–658.

Ixia (2013) *Quality of Service (QoS) and Policy Management in Mobile Data Networks*, Technical Report.

Klein, S., Karla, I. and Kuehn, E. (2011) 'Potential of intra-LTE, intra-frequency load balancing', *Vehicular Technology Conference*, Budapest, 15–18 May, pp.1–5.

Lei, L., Huang, A., Hua, C., Wu, Z., Qian, J., Shen, L., Chen, X. and Zhang, Y. (2011) 'Load balancing between TD-SCDMA and GSM systems with asymmetric traffics', *Communications and Networking in China (CHINACOM), 2011 6th International ICST Conference on*, Harbin, 17–19 August, pp.289–294.

Li, D., Yan, B. and Tao, J. (2012) 'Research for service quality and congestion control on the end to end network', *IEEE International Conference on Oxide Materials for Electronic Engineering (OMEE)*, pp.711–714. DOI:10.1109/OMEE.2012.6343671.

Li, Z., Wang, H., Pan, Z., Liu, N. and You, X. (2011) 'Joint optimization on load balancing and network load in 3GPP LTE multi-cell networks', *Wireless Communications and Signal Processing (WCSP), 2011 International Conference on*, Nanjing, 9–11 November, pp.1–5.

Munoz, P., Barco, R., de la Bandera, I., Toril, M. and Luna-Ramirez, S. (2011) 'Optimization of a fuzzy logic controller for handover-based load balancing', *2011 IEEE 73rd Vehicular Technology Conference*, pp.1–5.

Radojevic, B. and Žagar, M. (2011) 'Analysis of issues with load balancing algorithms in hosted (cloud) environments', *MIPRO, 2011 Proceedings of the 34th International Convention*, 23–27 May, pp.416–420.

Sivagar, M.R. and Prabakaran, N. (2021) 'Load balancing in real time mechanism using advanced real-coded genetic algorithm in LTE networks', *Asian Conference on Innovation in Technology (ASIANCON)*, pp.1–8. DOI:10.1109/ASIANCON51346.2021.9544750.

Soldani, D., Li, M. and Cuny, R. (2006) *QoS and QoE Management in UMTS Cellular Systems*, John Wiley & Sons, Ltd.

Song, W., Zhuang, W. and Cheng, Y. (2007) 'Load balancing for cellular/WLAN integrated networks', *IEEE Network*, Vol. 21, No. 1, pp.27–33.

Truina, D. and Furuskar, A. (2005) 'Traffic steering and service continuity in GSM-WCDMA seamless networks', *IEEE Explore*, Vol. 1, pp.77–82.

Vishwakarma, S.K. and Pavithra, H. (2022) 'Performance analysis of different load balancing algorithms in SDN based data center networks', *International Journal of Engineering Research & Technology*, Vol. 11, No. 7.

Zakia, U. and Ben Yedder, H. (2017) 'Dynamic load balancing in SDN-based data center networks', *8th IEEE Annual Information Technology, Electronics and Mobile Communication Conference*, pp.242–247. DOI:10.1109/IEMCON.2017.8117206.