A novel scheme for unified streamlined traffic management in 5G backhaul network

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ABSTRACT

The issues associated with the 5G backhaul network act as the underlying reason for concern. Existing literature towards the 5G backhaul network offers various ranges of sophisticated schemes that are yet to possess open-end issues. Therefore, the proposed study introduces a novel scheme for effective 5G backhaul network traffic management. The scheme hypothesizes that if an efficient gateway node is selected, it can better communicate between the macro-base station and the core network. The study contributes to developing a sophisticated system design to identify the blockage region, a macro-base station, and a small base station. These attributes incorporate the capability of a gateway node to identify the bottleneck condition during peak traffic situations in the 5G backhaul network. The study outcome shows better communication performance in contrast to the existing system. The study outcome shows the proposed scheme to offer 47% increased throughput, 80% reduced latency, and 55% reduced algorithmic processing time in contrast to existing schemes.

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1. INTRODUCTION

Every new generation of wireless networks delivers faster speeds and more functionality to smartphones. First generation (1G) introduced the first cell phones, 2G let users' text for the first time, 3G brought online activity, and 4G delivered the speeds users enjoy today [1]. But as more users come online, 4G networks have just about reached the limit of their capabilities. The technology is headed toward 5G, the next generation of wireless networking technologies [2]. It can handle a thousand times more traffic than today's networks and be up to 10 times faster than 4G long-term evolution (LTE) [3]. 5G is the foundation for various advanced technologies, e.g., virtual reality, autonomous driving, internet of things. 5 brand new technologies emerge as a foundation of 5G millimeter waves, small cells, massive multiple-input multiple-output (MIMO), beamforming, and full-duplex. Smartphones and other electronic devices use particular frequencies on the radio frequency spectrum, typically those under six gigahertz [4]. But these frequencies are starting to get more crowded. Carriers can only squeeze huge data bits on the same amount of radio frequency spectrum. As more devices come online, the users will start to see slower service and more dropped connections [5]. Researchers are experimenting with broadcasting on shorter millimeter waves that fall between 30 and 300 gigahertz [6]. This spectrum section has never been used for mobile devices; opening it up means more bandwidth for everyone. But there is a catch. Milli-meter waves cannot travel well through buildings or other obstacles and tend to be absorbed by plants and rain. There will be a need for technology with small cell networks to get around this problem. Today's wireless networks rely on large, high-powered cell towers to broadcast their signals over long distances. Still, it is to be noted that higher-frequency millimeter waves have a more challenging time travelling through obstacles. It will mean that if a user moves behind one, the user will lose the signal. Using thousands of low-power mini-base stations and small cell networks would solve that problem. These base stations would be much closer together than traditional towers, forming a relay team to transmit signals around obstacles. This would be especially useful in cities as the user moved behind an obstacle. The user's smartphone would automatically switch to a new base station in a better range of his device, allowing him to keep his connection. Next is massive MIMO. Today's 4G base stations have about a dozen ports for antennas that can handle all cellular traffic, but massive MIMO base stations can support about a hundred ports. This could increase the capacity of today's networks exponentially. Today's cellular antennas broadcast information in every direction at once, and all those crossing signals could cause serious interference, which is solved using beamforming. The backhaul network is introduced to improve communication in the 5G network, which bridges the communication between the radio access network and the mobile network. The wireless backhaul solution currently comes in different microwave, millimeter-wave, and free-space optics ranges. However, it is reported to be associated with various challenges, i.e., i) massive traffic at supercell leading to bottleneck conditions, ii) higher deployment cost, iii) catering up demands of long-distance reachability, iv) supporting constantly increasing demands of capacity, and v) complying with highly reduced latency demands.

The background of the proposed study is briefed with respect to existing studies with the 5G backhaul network. Researchers have presented different methodologies to solve 5G network performance issues [7]–[10]. The work carried out by Betzler *et al.* [11] has utilized the software define network (SDN) to formulate a unique architectural design that integrates 4G and 5G, focusing on small cell deployment. A unique system model is presented that can reconfigure the data plane in SDN, addressing failures of a communication channel in 5G. The existing system has also witnessed a unique application-based study of using a 5G backhaul network focusing on quality-of-experience (QoE). According to a survey by Ge *et al.* [12], the transmission of highly high-definition multimedia streaming will eventually lead to the consumption of resources. This problem was solved using an experimental approach by streaming video using a geostationary satellite. Another unique study by Zola and Martin-Escalona [13] discussed the effect of user association in the 5G network, which must be investigated for sorting out issues associated with CO_2 consumption, increasing cost, switching process, and tedious base station management. The authors have used integer linear problems to develop this model. The work carried out by Park and Song [14] has emphasized overusing caching-based concepts along with using content-centric networks and SDN to improve streaming services. At the same time, there are increasing areas of interest in considering case studies of millimeter-wave 5G networks focusing on controlling traffic. Work considering this case has been carried out by Yu *et al.* [15], where clustering issues associated with joint transmission have been investigated. The study objective was to control cumulative 5G backhaul traffic adhering to the condition to meet the transmission rate demands. According to the author, the optimal solution to such issues is dynamic programming leading to low channel capacity consumption.

A study towards cost optimization was witnessed in the model presented by Ge *et al.* [16], where the deployment strategy of the gateway was used over a wireless backhaul network in 5G. A unique cost optimization approach was witnessed in this work, focusing on increasing cost efficiency, which is reported to be performing better than the conventional shortest path technique in a 5G wireless system to support a backhaul network. A study on heterogeneous networks in 5G networks investigated the mobile network. The work carried out by Haddaji *et al.* [17] has presented a multitenant model to optimize operational cost. The study model contributes to offering virtualized 5G backhaul services towards cost optimization. This technique utilized a game theory to solve the issue. The adoption of game theory has also been seen in the work by Liu *et al.* [18], where resource allocation for better communication is boosted by introducing a unique incentive concept leading to the generation of a distributed algorithm. Adopting a similar virtualized environment was also witnessed in the work conducted by Nahum *et al.* [19]. The objective was to enhance the virtualized environment by presenting a unique testbed using open-source technologies. The author has used artificial intelligence to design this testbed. Zhang *et al.* [20], focusing on resource management considering heterogeneous networks in 5G backhaul, work towards adopting virtualization has also been carried out. The author has addressed the issues connected with overhead reduction and load balancing, where the problem solution is particle swarm optimization. The study has also used priority queues for traffic management, especially for scheduling downlink traffic.

From the resource management viewpoint, the work carried out by Mowla *et al.* [21] has addressed the energy issues associated with adopting millimeter wave and optical networks. According to the author, a singular backhaul technology is never enough to support variants of traffic load on a 5G network. The author has used a heuristic-based energy-efficient technique to solve this problem. Another study addressing energy issues was also reported by Al-Quzweeni *et al.* [22]. The author has used mixed integer linear programming to control power depletion over the virtualized environment. According to the model, if the position of the virtual machine and utilization of the servers for the virtualized environment is carried out effectively, it offers significant benefits towards energy conservation in 5G backhaul network operation. Further, the study has also used a genetic algorithm to validate the model. Further energy-based problems have been discussed in the work of Malandrinno *et al.* [23]. El Haber *et al.* [24] have addressed the offloading task challenge and energy minimization using convex optimization approximation.

Existing approaches have also witnessed consideration of MIMO based architectures used for accessing the 5G backhaul network. Such work is reported by Bonfante *et al.* [25], where adopting a directive antenna pattern and partitioning optimal resources is carried out. This approach was claimed to offer rate improvement in contrast to conventional MIMO. However, the work does not discuss its resistivity from the unreliable transmission reported in the model presented by Vu *et al.* [26]. This work addresses issues towards optimal path selection over a 5G network. The author has used a stochastic optimization approach using a mathematical model and reinforcement learning method to select the optimal communication path. Issues associated with the adoption and deployment of millimeter-wave in 5G backhaul networks are also addressed in the work of Ortiz *et al.* [27]. According to the authors, the priorly deployed implementation bears impractical logic and has complications. This problem is solved by using a learning algorithm that works in a semi-supervised distributed manner to reduce the latency of the network. The existing system has also been studied by optimizing the 5G network using radio-based mapping methodology, as seen in the work of Rodriguez *et al.* [28]. The idea is to prevent issues associated with interference using the strategy of cell association using stochastic geometry, where the probability derivation of coverage and association of the user is carried out. A study towards scheduling is reported in the work of Saad and Abdallah [29] using a succinct optimization concept. Kalantari *et al.* [30] have used an iterative scheme to control the downlink's transmit power.

It can be seen that various studies are being carried out towards the 5G backhaul network with the introduction of different variants of methods. Various methods that have been witnessed to be adopted in existing approaches are software define network, caching-based concept, content-centric network, dynamic programming, cost optimization, game theory, artificial intelligence, particle swarm optimization, heuristic-based energy efficient technique, mixed-integer linear programming, genetic algorithm, the directive pattern of the antenna, stochastic optimization approach, reinforcement learning method, and semi-supervised distributed. Therefore, the research problem is identified as: i) The majority of the implemented methods are iterative and hence have higher chances of leading to computational burden over the long run; ii) None of the existing research work has emphasized enhancing the feature of gateway management concerning traffic control in the backhaul network in 5G; iii) There are few studies towards blockage associated with small/macro base stations, and neither are there any studies towards exploring its association with core network concerning the gateway; and iv) Hence, lesser significance is offered to the gateway, which can offer effective control over traffic management if incorporated with efficient features. Therefore, the problem statement of the proposed study can be stated as "It is a complex computational task to identify specific criteria for choosing the best operation for improving the operation in gateway system in 5G backhaul network."

The solution presented in the research work is an analytical model for selecting an optimal gateway node in a 5G network. One of the major problems of the 5G backhaul network is to achieve an effective load balancing as capacity per device decreases with the growth in the number of users as the gateway node is over-saturated. This is inevitable for even a mobile grid with a higher density. Existing research-emphasizes the core network more than the backhaul network. The proposed strategy will harness the information related to traffic and the dynamic topology of both backhaul and core networks. This stage will focus on implementing software-defined networks for the 5G network to ensure its compatibility with the upcoming compatibility of the 5G network. An analytical model will be built to use the multiple numbers of base stations assigned to a singular gateway node (*i.e.*, many-to-one relationship) to reach the convergence factor. The system will also develop a decision-making module in the selection process of gateway nodes to control the traffic flow and investigate the connectivity of base stations with the optimally selected gateway out of many other gateways. The proposed model will also investigate all the possibilities of the data forwarding process using multi-hops in both the core network and backhaul network in 5G. Finally, the investigation will utilize the link obtained by this model and check how far the optimal condition is benefitting the traffic management in the 5G network. The organization of the manuscript is as follows: section 2 presents a discussion of the adopted research methodology, while section 3 highlights the accomplished result after the execution of the proposed model. Section 4 presents the conclusion of the manuscript.

2. METHOD

This section discusses the method and design aspect of the operation, which is carried out within the gateway system in the 5G backhaul network. In the line of adopted research methodology, the proposed scheme considers two types of base station i.e., macro base station and small base station. In order to retain better practicality of approach, the macro base station is considered to have wired access to backhaul, while the small base station is wirelessly connected to the macro base station. The system assesses the coverage rate in the form of distribution frequency associated with the data rate that is acquired by the user equipment from dual sources of strategic classification of the macro base station. In the primary strategy, both the backhaul network and access are split for dynamically allocating cumulative channel capacity. In the secondary strategic classification, a fixed partition is assigned for backhaul communication and access in the 5G network. One of the essential novelties of the adopted research methodology is to carry out a characterization of the combined assessment of signal quality over noise power associated with a 5G backhaul network and access point, especially when the small base station is connected to the user equipment. The core notion of this methodology is also to find the best position of the base station in the 5G backhaul network, which further contributes towards establishing a relation between the variation of size of the small base station towards the availability of dedicated channel capacity to the 5G backhaul network. The scenario of the adopted research methodology implementation is shown in Figure 1.

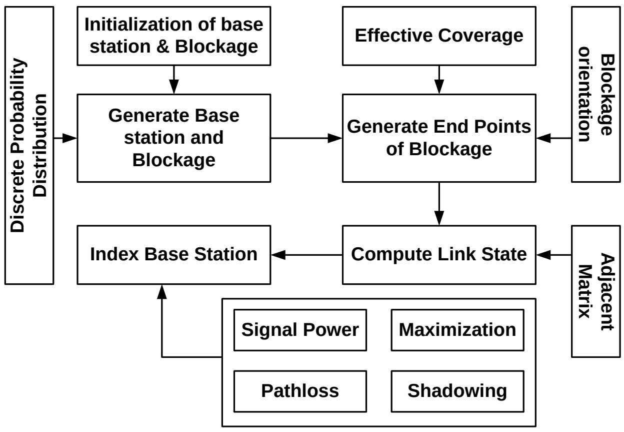

Figure 1. Research methodology adopted

The proposed system design is constructed considering user equipment to be uniformly sampled in random order. The origin of the presented coordinate system is shifted to the position in perspective of this user that is further served by the base station (BS). The implementation assumes that all the macro base station (MBS) is powered by a backhaul network with maximized capacity. It will infer that MBS are linked with the core network using high speed connectivity of data transfer. Further, the system design considers the small base station (SBS) themselves to be a backhaul network by MBS, while open access-based criteria are used for all the operations of BS. It will mean that user equipment will be either linked with SBS or MBS on the basis of power. The algorithms implemented for accomplishing the discussed research methodology in the prior section are as:

Algorithm 1. Algorithm for generating base station and blockage

Input: m, s, b
Output: m_r, s_r, b_r
Start
1. init m, s, b
2. $r_{mo} \leftarrow f_1(m, s, b)$
3. $\alpha \leftarrow f_2(r_{mo} | c_a)$
4. $\alpha \rightarrow m_r, s_r, b_r$
End

According to this algorithm, the proposed schemes take the input of macro base station (m), small base station (s), and blockage (b) that, after processing, yields an outcome of randomly selected MSB (m_r), randomly selected SBS (s_r), randomly selected blockage (b_r). The first step of this algorithm is to initialize the input parameters (Line-1), followed by applying a function $f_1(x)$, which is responsible for generating a random mathematical object r_{mo} (Line-2). Further, another function, $f_2(x)$, is constructed, which is responsible for applying a discrete probability distribution on the basis of coverage area c_a (Line-3) and r_{mo} in order to generate a matrix α. This matrix finally generates the outcomes of randomly selected MSB, SBS, and blockage. The first step of the design aspect is towards generating MBS, SBS, and blockage randomly as a matter of initializing the object. The study uses discrete probability distribution considering the coverage area of the cell. All the objects are randomly selected for faster computation within the reachability of the base station. The next part of the operation generates the Poisson point process associated with MBS, SBS, and blockage. For this purpose, the study computes an effective coverage radius considering randomly selected MBS, SBS, and blockage along with individual radius. This operation results in the two-dimensional coordinate system (x, y) representing the location where the singular gateway node is anticipated.

Therefore, the multiple base station is allocated for the singular gateway node based on this preliminary criterion to be within the effective coverage radius. This operation also discloses the practical location of all essential components, e.g., MBS, SBS, and blockage. Finally, the block's orientation is computed to yield a two-dimensional coordinate position of the endpoints of blockage. It will mean that the proposed system can localize the location of blockage so that necessary measures can be undertaken by the gateway node while permitting ongoing transmission over the 5G backhaul network. This operation also contributes towards the simplified operation of the gateway system for decision-making. The next part of the implementation is associated with the generation of block endpoint coordinates where the input to the next algorithm is the outcome accomplished from the prior algorithm, i.e., macro base station (m), small base station (s), and blockage (b). The algorithmic steps are as:

Algorithm 2. Algorithm for generating block endpoints coordinates
```
Input: m_r, s_r, b_r
Output: b_ep
Start
1. E_ca ← ( m_r, s_r, b_r)|i_r
2. E_ca(X, Y) → Pos(m, s, b)
3. b_ep(x, y) ← f_3(Pos(b))
End
```

According to the above-mentioned algorithm, the processing leads to the generation of block end point coordinates, i.e., b_{ep}. It should be noted that the proposed algorithm considers that a one-hop communication link is used to serve user equipment when linked with MBS, while a dual-hop communication link is used in case the user equipment is linked with SBS. Thereby, an access link is generated between BS and user equipment, while a backhaul link is generated between SBS and MBS. In order to clearly understand this operation, the proposed scheme uses the Poisson point process in order to model the position of the user and BS. The algorithm takes the input parameters m_r, s_r, b_r along with individual radius i_r of user equipment in order to generate effective coverage radius E_{ca} (Line-1). Further, the matrix of E_{ca} is used for generating position information class Pos considering attributes of *m*, *s*, and *b* (Line-2). Further, the algorithm uses location information of blockage, i.e., $Pos(b)$ in order to generate the coordinates of blockage end points b_{ep} to fulfil the outcome accomplishment of this algorithm (Line-3). After the block endpoints have been accomplished in the prior algorithm, the proposed system now proceeds towards the computation of the state of communication link among various entities of MBS, SBS, and user equipment user equipment (UE). The algorithm developed for this purpose is as:

Algorithm 3. Algorithm for link state among entities
```
Input: b_ep, L
Output: λ
Start
(L_a, size(L_b) → new(L_e)
(L_c, size(L_d) → new(L_f)
A_mat ← f_4(new(L_e), new(L_f))
b_ep(x, y) → A_mat
A_mat ← f_5(L_var)
A_mat → λ_var1
If λ_var1=0
   obtain λ_var1
End
End
```

The algorithm takes the input of block endpoint (b_{ep}) and location (L) that, after processing, yields an outcome of link state (λ). As the above-mentioned algorithm is meant to compute the state of the link for three entities, therefore, some of the variables used in this algorithm will represent three different entities. The algorithm takes the input of location (L) and the size of the location of other entities in order to generate new location information (Line-1 and Line-2). In the case of link computation between MBS and UE, the algorithm will generate a new location of MBS L_e considering the location of MBS L_a and the size of the location of user equipment L_b (Line-1). Further, the new location of user equipment L_f is generated from the location of user equipment L_c and the size of the location of MBS L_d (Line-2). Hence, in the case of establishing a link state for SBS and UE, the variables L_a and size (L_b) will represent the location of SBS and the size of the location of UE while $new(L_e)$ will represent the new location of SBS (Line-1). Further, the variable L_c and $size(L_d)$ will represent the location of user equipment and the size of the location of SBS in order to generate a new location of UE, i.e., $new(L_f)$ (Line-2). Hence, in the case of establishing a link state for MBS and SBS, the variables L_a and size (L_b) will represent the location of MBS and the size of the location of SBS, while $new(L_e)$ will represent the new location of MBS (Line-1). Further, the variable L_c and $size(L_d)$ will represent the location of SBS and the size of the location of MBS in order to generate a new location of SBS, i.e., $new(L_f)$ (Line-2).

Further, both the generated new location information, i.e., $new(L_e)$ and $new(L_f)$, are subjected to a new function $f_4(x)$, which results in constructing an adjacent matrix A_{mat} (Line-3). This adjacent matrix A_{mat} also considers the input of blockage endpoints, i.e., $b_{ep}(x, y)$ (Line-4). This operation of generation of the adjacent matrix is the same for link state computation for i) MBS and UE, ii) for SBS and UE, and iii) for SBS and MBS. The algorithm further implements a function $f_5(x)$ which is responsible for performing matrix reshaping operation considering the input of location information L_{var} to generate a reshaped adjacent matrix A_{mat} (Line-5). In the case of link state computation for MBS and UE, the variable L_{var} will consider the location of MBS and SBS, while the L_{var} considers SBS and UE for link state computation for SBS and UE. In the case of computation of MBS and SBS, the algorithm considers L_{var} to be the location of SBS and the location of MBS. The generated reshaped adjacent matrix A_{mat} now yields preliminary information of link state λ_{var1} (Line-6), where the suffix $var1$ will refer to the link state for individual use-cases of entities, i.e., $var1$ will represent the intersected state of link for MBS and UE, SBS and UE, and MBS and SBS. This leads to further checking a logical condition where the intersected link state for each band of entities (MBS and UE, SBS and UE, and MBS and SBS) is equal to zero (Line-7). This will finally lead to a unique outcome of link state λ_{var1} (Line-8). The complete algorithm is pictorially shown in Figure 4. The computation for extracting the link state is carried out by constructing a link matrix for MBS and user equipment, SBS and user equipment, and MBS with SBS, respectively. The idea is to construct an adjacent matrix considering the new location of MBS, user equipment, and SBS. The outcome matrix is further used for generating information about the state of the link for MBS, user equipment, and SBS adhering to a simplified condition of zero states. The core idea of this link state computation is to ensure the control of information associated with all elements by the gateway node as a contribution to the study, unlike any existing approaches.

The next part of the implementation is associated with indexing both the type of base station *i.e.*, MSB and SBS. The system designs relate to two different methodologies for obtaining the indexing of the base station along with meeting the power demands. The primary approach for this process is related to indexing MBS, which takes the input of newly generated outcome from the prior algorithm, i.e., link state (λ), location of UE (L_{UE}) and location of MBS (L_m) that after processing yields index of MBS (I_m). The steps of this algorithm are as:

Algorithm 4. Algorithm for indexing MBS

```
Input: λ (Link State), L_UE (Location of UE), L_m (Location of MBS)
Output: I_m (index of MBS)
Start
1. E_d ← (L_UE, L_m)
2. S_p(p, t_p) → f_6(E_d, λ_m,UE)
3. P_max, I_m ← arg_max(S_p)
End
```

The prime initiating point of this algorithm is to obtain the effective distance E_d considering the input parameters (Line-1). Further, the size computation of the matrix holding location information of MBS is carried out and is further used for computing effective distance. An explicit function $f_6(x)$ is used for computing signal power on the basis of pathloss exponent p and transmit power t_p (Line-3). It is to be noted that computation of the signal power uses the state of link for MBS and UE for effective computation. Further, the proposed scheme applies a maximization principle on signal power S_p in order to obtain maximized power UE and MBS as well as an index of MBS, i.e., I_m (Line-3). A similar algorithm is slightly fine-tuned in order to obtain the indexing of the SBS. The initial steps of the indexing operation for SBS are similar to that of the previous algorithm only with a difference of input of location of SBS instead of MBS in order to compute an effective distance E_d. Another new inclusion is the mechanism of computation of signal power, which considers the computed value of shadow coefficient and bias factor apart from the pathloss exponent seen in the prior algorithm. The computation results in the signal power of SBS and UE, where a similar maximization function is implemented in order to obtain indexing of SBS and maximized power of UE and SBS. The location information of MBS, SBS, and user equipment is subjected to spatial processing to obtain an adequate distance. This is further followed by computing the shadowing coefficient that leads to the generation of signal power considering pathloss exponent and bias factor. Finally, a maximization function is computed concerning signal power to know the maximized power and index of respective system actors (MBS and SBS). The contribution of the proposed system design is that it performs highly progressive computation without any iterative scheme of enhancing communication carried out in the existing system of implementation. Hence, the extensive dynamic information of gateway nodes assists in better traffic management. The following section discusses the results obtained.

3. RESULTS

The proposed system considers the practical test environment of the heterogeneous network as it is frequently adopted in most existing approaches. The proposed system is scripted in MATLAB considering the implementation of RFC 8822 in order to deploy the 5G convergence plane for wireless and wireline for encapsulation of the user plane. The deployment of this RFC introduces an encapsulation mechanism that offers supportability of traffic multiplexing associated with multiple sessions to offer quality of service in 5G communication. Further, the simulation parameters were used for assessing the connectivity probability in the form of a function for finally determining the coverage rate. Finally, the algorithms were sequentially evaluated in order to arrive at the outcome. Table 1 highlights the simulation parameters adopted for the proposed assessment.

Table 1. Simulation parameters

Parameters	Values
Density of UE	950 km2
Bias attribute	[1,1]
Power of noise	-175 dB
Path loss exponent	2.5
Transmit power (BS)	35 dBm

The study considers the variable location of MBS within the cell where the line-of-sight model associated with the urban communication scenario is considered for path loss between 2.5-30 GHz. The comparative analysis considers the homogeneous network HomNet and the conventional heterogeneous network HetNet. The prime reason for the adoption of HomNet and HetNet as conventional networks in the analysis of the proposed work is due to multiple reasons, viz. i) From commercial perspective, it is noted that HomNet can offer cost-effective and predictable capacity and coverage in urban and rural area with mobile broadband services with relatively static form of traffic; ii) Adoption of HetNet is reported to be suitable for high-traffic areas, indoor coverage, and large-scale device-to-device communication in 5G; iii) Apart from this, both forms of conventional network systems can actually contribute to network densification, which is essential for improving coverage in 5G using a higher density of base stations; and iv) A joint operation of both these conventional network systems are also known to offer capacity enhancement and quality of service. Hence, HomNet and HetNet are more deployed in a 5G environment from the practical perspective and hence are considered to be subjected to comparative analysis with the proposed system.

The evaluation considers a 1-20 Mbps average rate for 2.5-30 GHz as poison distribution for data arrival. The analysis is carried out over a simulation iteration test environment, which increases the traffic rate. Both conventional systems (HomNet and HetNet) are assessed on a similar testbed with the proposed system to draw logical, conclusive outcomes. Figure 2 highlights that the proposed system offers better throughput performance with consistency compared to the existing mechanism concerning downlink transmission.

Referring to Figure 2, the reason for consistency is that the cumulative channel capacity and MBS are divided between the proposed unified framework on access and backhaul links. The pattern of linear characteristic is due to the usage of dual links from MBS to user equipment over SBS during rate distribution. However, it still excels better compared to conventional approaches. A similar trend of betterment in latency can also be observed in Figure 3. Although, in increasing order, the proposed system offers better latency control than the existing approach. One reason is the absence of iterative steps in the proposed system, unlike HetNet and HomNet, to accomplish a successful downlink transmission. The novelty in the outcome is that irrespective of the increasing load of traffic and the possible presence of artefact in flow; the proposed system offers a better streamlined flow of communication in contrast to the iterative and complex mechanism of the existing system. The outcomes presented in Figure 2 and 3 showcase that the proposed study model is capable of identifying the bottleneck condition captured from traffic information that is further subjected to algorithms in order to make a precise decision making of relaying services using a 5G network system. Hence, the system not only offers lower latency and increased throughput but also offers a better sustainable data transmission scheme supported for multiple variants of applications hosted in 5G-based services.

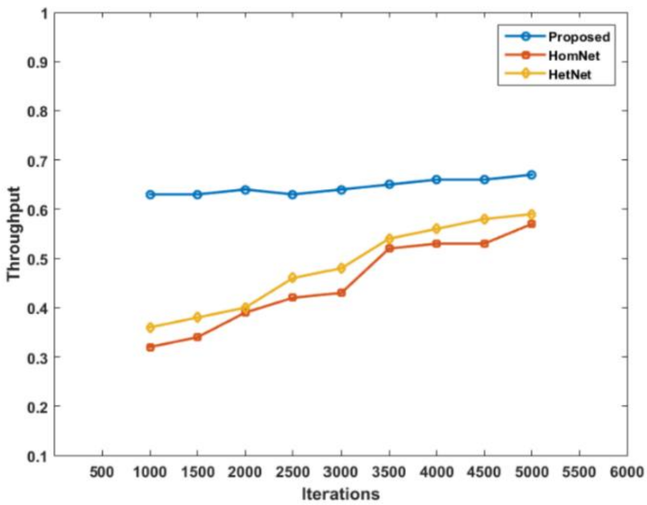

Figure 2. Comparative analysis of throughput

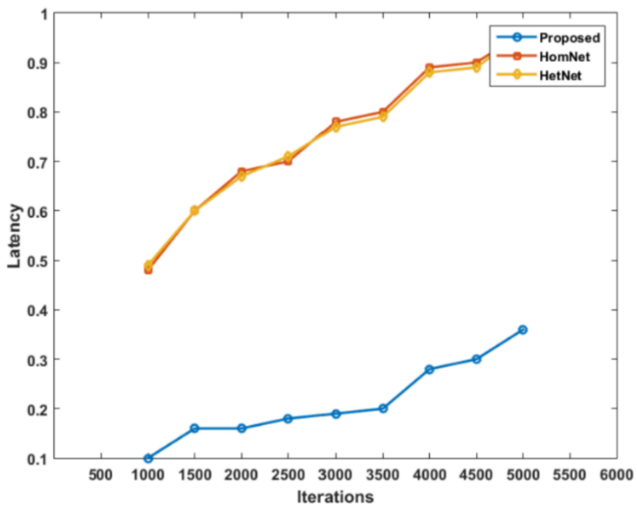

Figure 3. Comparative analysis of latency

From the outcome exhibited in Figure 4, it can be noted that the proposed system ($t = 0.2668$ s) offers highly reduced response time in contrast to the conventional mechanism of HomNet ($t = 0.734$ s) and HetNet ($t = 0.9117$ s). There are multiple key findings from the outcome of the proposed study to offer better insight into its effectiveness as follows: i) although HomNets are known for their cost-effectiveness in perspective of deployment, it is noted that it is not capable enough to fine-tune itself to the altering patterns of traffic in 5G especially during variations of traffic intensity. This fact can be realized by reduced throughput of HomNet, as shown in Figure 2. And ii) HetNets are well-claimed to offer improved spectral efficiency where the traffic offloading is carried out to smaller cells from macro cells. They are also known for enhancing network performance; however, when HetNet is exposed to the proposed testbed, it is found that it encounters excessive computational effort with overlapping coverage areas and diverse cell types. This fact can be realized from reduced latency in Figure 3 and increased algorithm processing time in Figure 4.

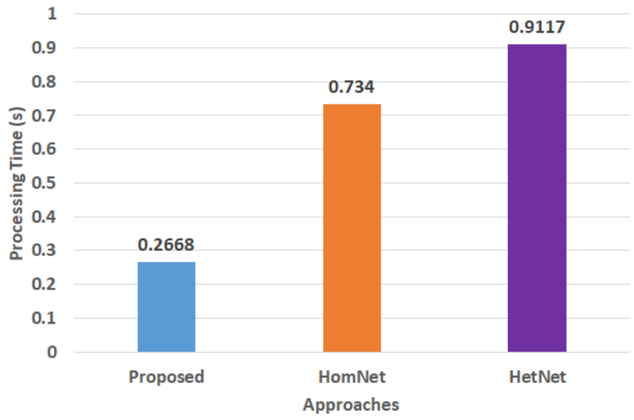

Figure 4. Algorithm processing time

Considering HetNet to be highly applicable towards emerging applications in 5G compared to HomNets, maintaining and deploying them incurs excessive cost in the perspective of small cells like picocells and femtocells. At the same time, the prime strength of the proposed system resides in its ability to index of base station based on multiple simplified parameters (signal power and pathloss.) and link state. Hence, a better service dissipation alternative is generated in the proposed study model with effective blockage management.

From the outcome accomplished in the study, it can be thereby stated that the proposed model assists in significantly improving network capacity by efficiently optimizing the network resources with better quality of service. While existing approaches are mainly found to be sophisticated approaches that deploy caching-based concepts, cost optimization, energy-efficient techniques, and artificial intelligence, the proposed scheme uses very simplified analytical modelling towards generating blockage followed by link state computation. This makes the proposed model much more worthy towards deploying in practical world scenarios with dynamic traffic management in 5G.

4. CONCLUSION

At present, there are various approaches towards managing the 5G backhaul network; however, none of the approaches are witnessed to emphasize gateway nodes. Hence, this paper hypothesizes that the efficient selection of a gateway node using a simplified scheme without iteration could result in better traffic management. From the result analysis, it is noted that HomNet and HetNet, the two popular approaches in 5G, cannot address the upcoming challenges, especially relating to dynamic traffic management that the proposed scheme is shown to be capable of. Apart from this, the proposed scheme not only offers a better quality of service, but its demands for computational resources are quite minimal in contrast to existing approaches. This model introduces an effective traffic management operation where core and backhaul networks are used for developing a unified architecture where MBS, SBS, and user equipment play a considerable role. The idea is also about consistent extraction of updated information of location and link-state associated with actors mentioned above to incorporate the better capability of a gateway node between MBS and core network. The study outcome exhibits proposed system offers approximately 47% and 80% improvement concerning throughput and latency, along with 55% significantly reduced algorithmic processing time. The outcome suggests the fair feasibility of the proposed study model in traffic management for backhaul networks supported by 5G network services. The limitation of the current work can be viewed as a highly focused target towards improving 5G services considering solving issues in traffic management. It is strongly believed that there is more scope for improving the current work by incorporating a scheduling approach. Hence, the future direction of work will be carried out towards solving the optimization problem of packet forwarding in a 5G backhaul network by adopting a novel scheduling approach.

REFERENCES

[1] P. J. Burke, "4G antipode: remote control of a ground vehicle from around the world," *IEEE Journal on Miniaturization for Air and Space Systems*, vol. 1, no. 3, pp. 150–153, Dec. 2020, doi: 10.1109/JMASS.2020.3018400.

[2] Y.-Y. Wang, Y.-L. Ban, and Y. Liu, "Sub-6GHz 4G/5G conformal glasses antennas," *IEEE Access*, vol. 7, pp. 182027–182036, 2019, doi: 10.1109/ACCESS.2019.2959603.

[3] J. Han and K. Kwon, "I/Q balance-enhanced wideband receiver front-end for 2G/3G/4G/5G NR cellular applications," *IEEE Transactions on Circuits and Systems I: Regular Papers*, vol. 67, no. 6, pp. 1881–1891, Jun. 2020, doi: 10.1109/TCSI.2020.2974486.

[4] H. Campanella, Y. Qian, C. O. Romero, J. S. Wong, J. Giner, and R. Kumar, "Monolithic multiband MEMS RF front-end module for 5G mobile," *Journal of Microelectromechanical Systems*, vol. 30, no. 1, pp. 72–80, Feb. 2021, doi: 10.1109/JMEMS.2020.3036379.

[5] H. Jin, L. Zhu, H. Zou, Y. Luo, S. Xu, and G. Yang, "A wideband dual-polarized antenna and its array with electrically down tilt function for 5G sub-6 GHz communication applications," *IEEE Access*, vol. 8, pp. 7672–7681, 2020, doi: 10.1109/ACCESS.2019.2959378.

[6] S. Shinjo *et al.*, "A 28GHz-band highly integrated GaAs RF frontend module for massive MIMO in 5G," *2018 IEEE MTT-S International Microwave Workshop Series on 5G Hardware and System Technologies, IMWS-5G 2018*, 2018, doi: 10.1109/IMWS-5G.2018.8484564.

[7] E. Wong, E. Grigoreva, L. Wosinska, and C. M. Machuca, "Enhancing the survivability and power savings of 5G transport networks based on DWDM rings," *Journal of Optical Communications and Networking*, vol. 9, no. 9, Sep. 2017, doi: 10.1364/JOCN.9.000D74.

[8] C.-C. Teng, M.-C. Chen, M.-H. Hung, and H.-J. Chen, "End-to-end service assurance in 5G crosshaul networks," in *2020 21st Asia-Pacific Network Operations and Management Symposium (APNOMS)*, Sep. 2020, pp. 306–309, doi: 10.23919/APNOMS50412.2020.9236977.

[9] I. Allal, B. Mongazon-Cazavet, K. Al Agha, S.-M. Senouci, and Y. Gourhant, "A green small cells deployment in 5G-Switch ON/OFF via IoT networks and energy efficient mesh backhauling," in *2017 IFIP Networking Conference (IFIP Networking) and Workshops*, Jun. 2017, pp. 1–2, doi: 10.23919/IFIPNetworking.2017.8264871.

[10] M. Jaber, M. A. Imran, R. Tafazolli, and A. Tukmanov, "5G backhaul challenges and emerging research directions: a survey," *IEEE Access*, vol. 4, pp. 1743–1766, 2016, doi: 10.1109/ACCESS.2016.2556011.

[11] A. Betzler, D. Camps-Mur, E. Garcia-Villegas, I. Demirkol, and J. J. Aleixendri, "SODALITE: SDN wireless backhauling for dense 4G/5G small cell networks," *IEEE Transactions on Network and Service Management*, vol. 16, no. 4, pp. 1709–1723, Dec. 2019, doi: 10.1109/TNSM.2019.2930745.

[12] C. Ge *et al.*, "QoE-assured live streaming via satellite backhaul in 5G networks," *IEEE Transactions on Broadcasting*, vol. 65, no. 2, pp. 381–391, Jun. 2019, doi: 10.1109/TBC.2019.2901397.

[13] E. Zola and I. Martin-Escalona, "A robust user association, backhaul routing, and switching off model for a 5G network with variable traffic demands," *IEEE Access*, vol. 8, pp. 96714–96726, 2020, doi: 10.1109/ACCESS.2020.2992330.

[14] G. S. Park and H. Song, "Cooperative base station caching and X2 link traffic offloading system for video streaming over SDN-enabled 5G networks," *IEEE Transactions on Mobile Computing*, vol. 18, no. 9, pp. 2005–2019, Sep. 2019, doi: 10.1109/TMC.2018.2869756.

[15] Y.-J. Yu, T.-Y. Hsieh, and A.-C. Pang, "Millimeter-wave backhaul traffic minimization for CoMP over 5G cellular networks," *IEEE Transactions on Vehicular Technology*, vol. 68, no. 4, pp. 4003–4015, Apr. 2019, doi: 10.1109/TVT.2019.2900379.

[16] X. Ge, S. Tu, G. Mao, V. K. N. Lau, and L. Pan, "Cost efficiency optimization of 5G wireless backhaul networks," *IEEE Transactions on Mobile Computing*, vol. 18, no. 12, pp. 2796–2810, Dec. 2019, doi: 10.1109/TMC.2018.2886897.

[17] N. Haddaji, K. Nguyen, and M. Cheriet, "TCO planning game for 5G multitenant virtualized mobile backHaul (V-MBH) network," *Journal of Lightwave Technology*, vol. 37, no. 24, pp. 6193–6206, Dec. 2019, doi: 10.1109/JLT.2019.2947543.

[18] Y. Liu, A. Tang, and X. Wang, "Joint incentive and resource allocation design for user-provided network under 5G integrated access and backhaul networks," *IEEE Transactions on Network Science and Engineering*, vol. 7, no. 2, pp. 673–685, Apr. 2020, doi: 10.1109/TNSE.2019.2910867.

[19] C. V. Nahum *et al.*, "Testbed for 5G connected artificial intelligence on virtualized networks," *IEEE Access*, vol. 8, pp. 223202–223213, 2020, doi: 10.1109/ACCESS.2020.3043876.

[20] H. Zhang, C. Huang, J. Zhou, and L. Chen, "QoS-aware virtualization resource management mechanism in 5G backhaul heterogeneous networks," *IEEE Access*, vol. 8, pp. 19479–19489, 2020, doi: 10.1109/ACCESS.2020.2967101.

[21] M. M. Mowla, I. Ahmad, D. Habibi, and Q. V. Phung, "Energy efficient backhauling for 5G small cell networks," *IEEE Transactions on Sustainable Computing*, vol. 4, no. 3, pp. 279–292, Jul. 2019, doi: 10.1109/TSUSC.2018.2838116.

[22] A. N. Al-Quzweeni, A. Q. Lawey, T. E. H. Elgorashi, and J. M. H. Elmirghani, "Optimized energy aware 5G network function virtualization," *IEEE Access*, vol. 7, pp. 44939–44958, 2019, doi: 10.1109/ACCESS.2019.2907798.

[23] F. Malandrino, C. F. Chiasserini, C. Casetti, G. Landi, and M. Capitani, "An optimization-enhanced MANO for energy-efficient 5G networks," *IEEE/ACM Transactions on Networking*, vol. 27, no. 4, pp. 1756–1769, Aug. 2019, doi: 10.1109/TNET.2019.2931038.

[24] E. El Haber, T. M. Nguyen, C. Assi, and W. Ajib, "Macro-cell assisted task offloading in MEC-based heterogeneous networks with wireless backhaul," *IEEE Transactions on Network and Service Management*, vol. 16, no. 4, pp. 1754–1767, Dec. 2019, doi: 10.1109/TNSM.2019.2939685.

[25] A. Bonfante *et al.*, "5G massive MIMO architectures: self-backhauled small cells versus direct access," *IEEE Transactions on Vehicular Technology*, vol. 68, no. 10, pp. 10003–10017, Oct. 2019, doi: 10.1109/TVT.2019.2937652.

[26] T. K. Vu, M. Bennis, M. Debbah, and M. Latva-Aho, "Joint path selection and rate allocation framework for 5G self-backhauled mm-wave networks," *IEEE Transactions on Wireless Communications*, vol. 18, no. 4, pp. 2431–2445, Apr. 2019, doi: 10.1109/TWC.2019.2904275.

[27] A. Ortiz, A. Asadi, G. H. Sim, D. Steinmetzer, and M. Hollick, "SCAROS: a scalable and robust self-backhauling solution for highly dynamic millimeter-wave networks," *IEEE Journal on Selected Areas in Communications*, vol. 37, no. 12, pp. 2685–2698, Dec. 2019, doi: 10.1109/JSAC.2019.2947925.

[28] A. C. Suarez Rodriguez, N. Haider, Y. He, and E. Dutkiewicz, "Network optimisation in 5G networks: a radio environment map approach," *IEEE Transactions on Vehicular Technology*, vol. 69, no. 10, pp. 12043–12057, Oct. 2020, doi: 10.1109/TVT.2020.3011147.

[29] M. Saad and S. Abdallah, "On millimeter wave 5G backhaul link scheduling," *IEEE Access*, vol. 7, pp. 76448–76457, 2019, doi:

10.1109/ACCESS.2019.2922146.

[30] E. Kalantari, H. Yanikomeroglu, and A. Yongacoglu, “Wireless networks with cache-enabled and backhaul-limited aerial base stations,” *IEEE Transactions on Wireless Communications*, vol. 19, no. 11, pp. 7363–7376, Nov. 2020, doi: 10.1109/TWC.2020.3010845.

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