Evaluation of the Effect of Propagation Models on a New Radio Resource Management Technique for Fifth Generation Mobile Systems

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Abstract

Network designers are doing their best to develop technologies that provide communication services to anyone, anywhere, and anytime. Since the mobile traffic is expected to increase at Compound Annual Growth Rate (CAGR) of 46% from 2017 to 2022, the fifth generation (5G) of mobile communications is becoming a reality; which is supported multimedia applications for a wide range of requirements including: increased data rates, reduced latency, improved coverage, and increased energy efficiency. Achieving the objectives of the fifth generation requires the use of effective radio resource management techniques to ensure that priority is given to the requirements of different services. Current resource management techniques rely on scheduling algorithms that provide an optimal allocation of resources to ensure maximum flow rate, but do not take into consideration the characteristics of services such as video conferencing and their requirements.

In this paper we propose a resource allocation algorithm that divides the applications into three groups according to the application requirements in terms of the data rate. We then evaluate the performance of this algorithm on a proposed fifth generation system that takes into account previous technologies such as LTE-A, Wi-Fi and WiMAX, as well as the latest technologies employed in the fifth generation, including mmWave connections and device to device (D2D) connections.

Keywords: 5G, D2D, mmWave, resource management, propagation models: Friis, Okumura Hata, Cost231.

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تقييم أداء نماذج الانتشار على تقنية إدارة الموارد الجديدة في منظومات الجيل الخامس للاتصالات النقّالة

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الملخص

يبذل مصممو الشبكات قصارى جهدهم لتطوير التقنيات التي توفر خدمات الاتصال لأي شخص في أي مكان وفي أي وقت. نظرًا للتزايد المتوقع في حركة المرور في منظومات الاتصالات النقّالة بمعدل نمو سنوي مركب (CAGR) يصل إلى 46% من عام 2017 وحتى عام 2022 ، فقد أصبح الجيل الخامس 5G من الاتصالات النقّالة حقيقة واقعة؛ وذلك لدعمه متطلبات تطبيقات الوسائط المتعددة المتمثلة بـ: زيادة معدلات البيانات، وتقليل زمن التلبث، وتحسين التغطية، وزيادة كفاءة الطاقة. يتطلب تحقيق أهداف الجيل الخامس استخدام تقنيات فعّالة لإدارة الموارد الراديوية لضمان إعطاء الأولوية لمتطلبات الخدمات المختلفة. تعتمد تقنيات إدارة الموارد الحالية على خوارزميات الجدولة التي توفر التخصيص الأمثل للموارد لضمان الحد الأقصى لمعدل التدفق، ولكنها لا تأخذ في الحسبان خصائص الخدمات مثل مؤتمرات الفيديو ومتطلباتها.

اقترحنا في هذا البحث خوارزمية تخصيص للموارد الراديوية تعتمد تقسيم التطبيقات إلى ثلاث مجموعات حسب متطلبات التطبيق من حيث معدل البيانات. وقمنا بتقييم أداء هذه الخوارزمية على نظام مقترح من الجيل الخامس يأخذ في الحسبان التقنيات السابقة مثل LTE-A و Wi-Fi و WiMAX ، بالإضافة إلى أحدث التقنيات المستخدمة في الجيل الخامس، بما في ذلك اتصالات الأمواج الميليمترية mmWave واتصالات تجهيزة لتجهيزة (D2D).

الكلمات المفتاحية: الجيل الخامس، اتصالات الأمواج الميليمترية، اتصالات تجهيزة لتجهيزة، نماذج الانتشار: المسار الحر – أوكومارا هاتا – كوست 231.

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1. Introduction

The exponential growth of wireless data services driven by mobile Internet and smart devices leads to investigation of 5G cellular networks. Since the current mobile systems may not be able to accommodate the expected traffic demands by 2022. 5G networks will have to fulfill a wide variety of user requirements, such as higher peak user data rates, reduced latency, enhanced indoor coverage, and improved energy efficiency [1, 2].

In order to meet such wide spectrum of requirements, 5G will integrate a variety of new technology components, e.g. massive multiple-input multiple-output (massive-MIMO), millimeter-wave (mm-wave) communications technologies, device-to-device (D2D) communications, machine-to-machine (M2M) communications, and multi-tier heterogeneous networks [3,4]. Thus, more advanced radio resource management (RRM) techniques are required to fulfill 5G systems requirements.

Several traditional radio resource management techniques were proposed in the literature, but may not be suitable for 5G networks, which needs high spectrum efficiency [5-7].

In this paper, we proposed a simplified radio resource management technique that takes into account application requirements. We evaluated the algorithm on a considered 5G network, based on multi-tier radio access technology. To study the performance of the algorithm, we used different propagation models and evaluate their effect on the system performance.

2. 5G Networks

The 5G networks will consist of nodes with heterogeneous characteristics and capacities (e.g., macrocells, small cells such as femtocells and picocells, and D2D user equipment), which will result in a multi-tier architecture. 5G wireless network is a real wireless world network with no limitations, to provide multimedia features [4].

5G networks will address six challenges that are not effectively addressed by 4G, which are: higher capacity, higher data rate, lower End to End latency, massive device connectivity, reduced cost and consistent quality of experience (QoE) provisioning [4].

Many key features will be introduced in 5G networks, such as, lower battery consumption, multimedia features with no limitations, efficient security approaches, and high resolution applications with large bandwidth.

3. Propagation Models

Network planning requires finding proper transmission channel depending on the various factors such as path loss, scattering, refraction, and absorption due to obstacles.

$$L(urban) = A + B \times \log_{10}(d) \qquad (2)$$

$$L(sub) = A + B \times \log_{10}(d) - C \qquad (3)$$

$$L(open) = A + B \times \log_{10}(d) - D \qquad (4)$$

$$A = 69.55 + 26.16 \times \log_{10}(f) - 13.82 \times \log_{10}(h_b) - a(h_m) \qquad (5)$$

$$B = 44.9 - 6.55 \times \log_{10}(h_b) \qquad (6)$$

$$C = 5.4 + 2 \times \left[\log_{10}\left({f}/{28}\right)\right]^2 \qquad (7)$$

There are many radio wave propagation models, which are considered in network design. We will focus on the following models:

3.1 Okumara Hata Model

This model is suitable for cities with many urban structures, but not many tall blocking structures, and served as a base for Hata models. Since Hata model established empirical mathematical relationships to describe the graphical information given by Okumura model. Okumura Hata model was built into three modes which are urban, suburban and open areas as defined by equations 2 to 9 [8].

$$D = 40.94 + 4.78\,[\log_{10}(f)]^2 - 18.33 \times \log_{10}(f) \qquad (8)$$

$$a(h_m) = 1.1[\log_{10}(f) - 0.7]\,h_m - [1.56\,\log_{10}(f) - 0.8] \qquad (9)$$

Where:

Carrier frequency: 150 MHz ≤ f ≤1500 MHz

Base station (BS) antenna height: 30 m ≤ h_b ≤200 m

Mobile station (MS) antenna height: 1 m ≤ h_m ≤10 m

Transmission distance: 1 km ≤ d ≤20 km

3.2 Cost231 Model

The COST231-Hata model extends Hata's model for use in the 1500-2000 MHz frequency range, where it is known to underestimate path loss. The model is expressed in terms of the following parameters:

Carrier Frequency (f_c) 1500-2000 MHz

BS Antenna Height (h_{mb}) 30-200 m

$$L_{dB} = A_0 - a(h_{mb}) + [44.9 - 6.55\log_{10}(h_{ms})]\;\log_{10}(d) + C_{AC} \qquad (10)$$

$$A_0 = 46.3 + 33.9\,\log_{10} f_c - 13.82\,\log_{10} h_{bt} \qquad (11)$$

$$a(h_{mb}) = 1.1\,[\log_{10}(f) - 0.7]\;h_{mb} - [1.56 \times \log_{10}(f_c) - 0.8] \qquad (12)$$

$$C_{AC} = \begin{matrix} 0\,dB & \text{for medium and suburban} \\ 3\,dB & \text{for metropolitan areas} \end{matrix} \qquad (13)$$

MS Antenna Height (h_{ms}) 1-10 m

Transmission Distance (d) 1-20 km

The path loss according to the COST-231-Hata model is expressed as given by equations from 10 to 13 [8].

4. Resource Scheduling Algorithms

Radio resources are allocated in both time and frequency domains. Along the time domain they are assigned every Transmission Time Interval (TTI). The time is divided in frames. Each 10ms frame is divided into ten 1ms sub-frames i.e. TTIs, with each subframe divided into two 0.5ms slots. Each slot consists of 7 OFDM symbols with normal Cyclic Prefix (CP).

In the frequency domain, the total bandwidth is divided in sub-channels of 180 KHz, each one with 12 consecutive and equally spaced OFDM sub-carriers. Resource Block (RB) which is formed by the intersection between a sub-channel in frequency domain and one TTI in time domain is the smallest allocable resource unit [8]. In the next section we will present major resource scheduling algorithms used in 4G networks.

4.1 First In First Out (FIFO)

First in first out algorithm is the simplest of all possible scheduling algorithms, but it is inefficient and unfair. The metric of i-th user on the k-th RB is described in equation (14) [9].

$$m_{i,k}^{FIFO} = t - T_i \qquad (14)$$

Where, t is the current time and T_i is the time instant when request was issued by i-th user.

4.2 Round Robin (RR)

The round robin is a fair scheduling algorithm since every terminal is given the same amount of resources; but it neglects the fact that terminals in bad channel conditions need more resources to carry out the same rate. The metric of RR is described in equation (15), which is similar to the one defined for FIFO. The only difference is that, in this case, T_i refers to the last serving time instant of the user [9].

$$m_{i,k}^{RR} = t - T_i \qquad (15)$$

4.3 Blind Equal Throughput (BET)

The blind equal throughput is a channel unaware strategy that aims at providing throughput fairness among all users. To avoid the unfair sharing of the channel capacity, the BET scheduler uses a priority metric which considers past average user throughput as in equation (16)[9].

$$m_{i,k}^{BET} = {}^{1}/_{\bar{R}^{i}\,(t-1)} \qquad (16)$$

Where $\bar{R}^{i}\,(t-1)$ is the average throughput of terminal over windows in the past. The smoothed value of $R^{i}(t)$ is computed using any weight moving average formula, e.g. equation (17) [9].

$$\bar{R}^{i}(\mathrm{t}) = \left(1-\frac{1}{\mathrm{T}}\right)\bar{R}_{i}(\mathrm{t}-1) + 1/T\,.\,\mathrm{R}^{\mathrm{i}}(\mathrm{t}) \qquad (17)$$

Where $\mathrm{R}^{\mathrm{i}}(\mathrm{t})$ is the instantaneous value of data rate at time instant t.

4.4 Maximum Throughput (MaxT)

Max throughput depends on Channel Quality Indicator (CQI) feedback reports that are sent by the user equipment (UE) to obtain data rate of an identical sub-channel for different terminals. This information can be used in the priority metric to prioritize users with good channel conditions over users with bad channel conditions. The priority metric for the MaxT scheduler is given in equation (18) [9].

$$m_{i,k}^{Max-T} = d_k^i(t) \qquad (18)$$

Where $d_k^i(t)$ is the expected data-rate for i-th user at time t on the k-th resource block. It can be calculated by considering the Shannon expression for the channel capacity as equation (19) [9].

$$d_k^i(t) = \log_{10}\left[1 + SINR_k^i(t)\right] \quad (19)$$

5. System model

We consider a system model consisting of one LTE eNodeB, centralized in cell with radius 2.5km, four millimeter wave nodes, twelve WiFi access points, and one WiMax access point. Figure (1) illustrates the nodes diversity in the cell.

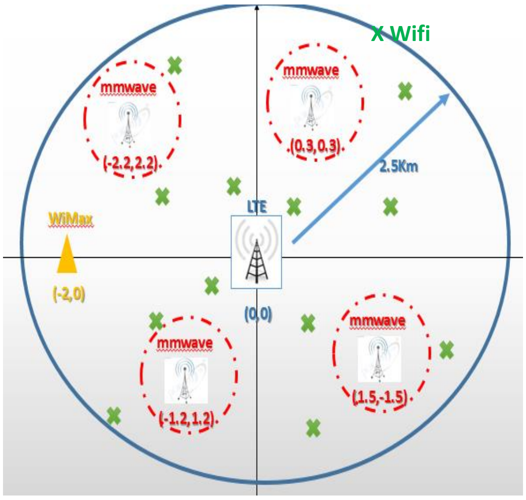


Figure 1: Nodes diversity in the cell.

The coverage distance for each node is described in table (1).

Table 1: Coverage distar… …ode/access point.

eNode/AP	LTE	mmWave	WiFi	WiMax
Coverage distance (Km)	≤ 2.5	≤ 0.3	≤ 0.1	≤ 50

The available resource … LTE node is shown in table (2), whereas table (3) shows the available resourc… …mWave. Table (4) shows data rates for WiFi standar… …ode provi… rate up to 4…

…ble resource… …n 1 frame = …ns, for LTE …

LTE …	1.4	3	5	10	15	20
[illegible]	[illegible]	300	500	[illegible]	1500	2000

Table 3: Available resource blocks in 1 frame = 10ms for 10 modes in mmWave.

mmWave mode	[illegible]	20	32	48	52
RB (Mbps)	240	400	640	960	1040
mmWave mode	64	72	80	92	100
RB (Mbps)	1280	1440	1600	1840	2000

Table 4: Available data rates in WiFi standrds.

Wi-Fi standards	1	2	3	4	5
RB (Mbps)	64	128	352	704	3456

5.1 Radio resource allocation algorithm

The proposed algorithm consists of three stages, which are:

Stage 1: Determine whether device-to-device communication is available or not.

We can achieve D2D communication in three ways [10]:

- Bluetooth connection with data rate 48Mbps, when the distance between the partners is less than 300 m.
- WiFi connection between the partners if the distance is less than 200 m, and provides data rate up to 250Mbps.
- LTE Direct between the partners with distance less than 500 m, and provides data rate between 5-10 Gbps.

Figure (2) shows the D2D algorithm flow chart.

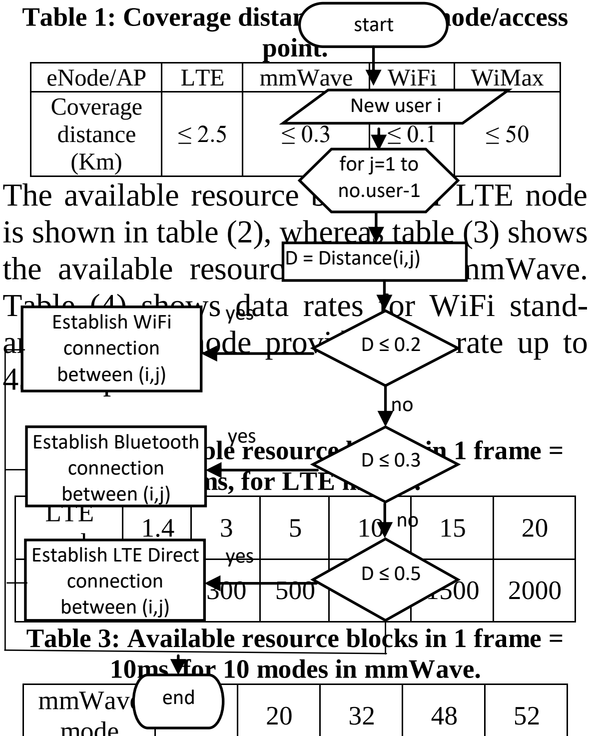


Figure 2: D2D algorithm flow chart.

Stage 2: Determine whether the user in node/AP coverage area or not.

We identify the available nodes/Aps for the user. Figure (3) shows the flow chart for technology determination algorithm.

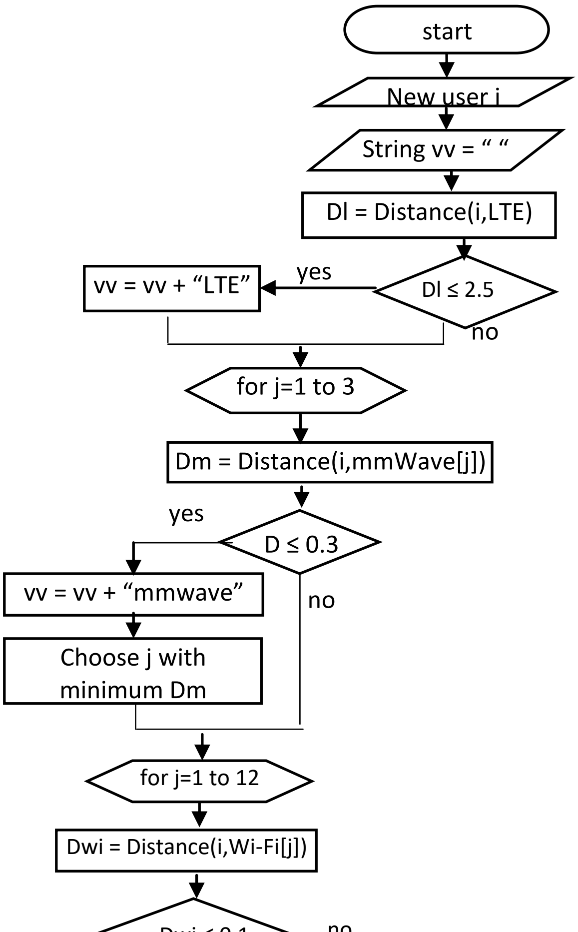


Figure 3: Flow chart of the technology determination algorithm.

Stage 3: Evaluate the allocated resource block to user for each technology.

We proposed a new resource block allocation algorithm that takes into account the application requirements. So we classify the users based on service priority into three groups namely, emergency calls, guaranteed users, and normal users.

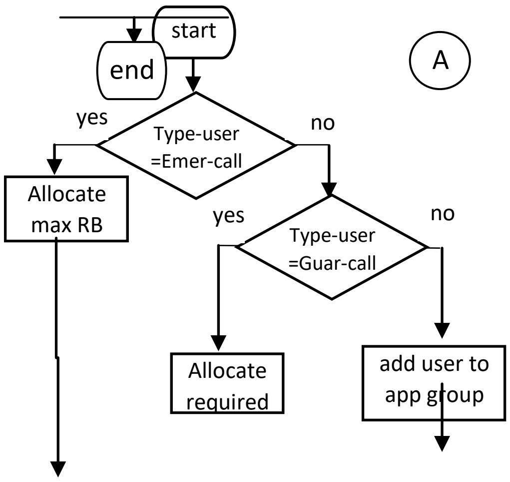
We always allocate emergency calls with the required resource without any delay. If there isn't enough resource, then we decrease the allocated resource for normal users.

In case of guaranteed users, which ask for a specific amount of resources, we allocate the required resource blocks for them even if we decrease allocated resource to normal users.

The normal users are classified into three groups, which are:

- Group 1: it includes chat, SMS, and web browsing applications, which requires about 32 Kbps.
- Group 2: it includes voice applications, such as voice over IP (VOIP) and requires approximately 64 Kbps.
- Group 3: it includes video applications, like video conferencing, video over IP, and video streaming, which requires between 0.5 Mbps up to 20 Mbps.

Figure (4) shows the flow chart of the proposed resource block allocation algorithm.



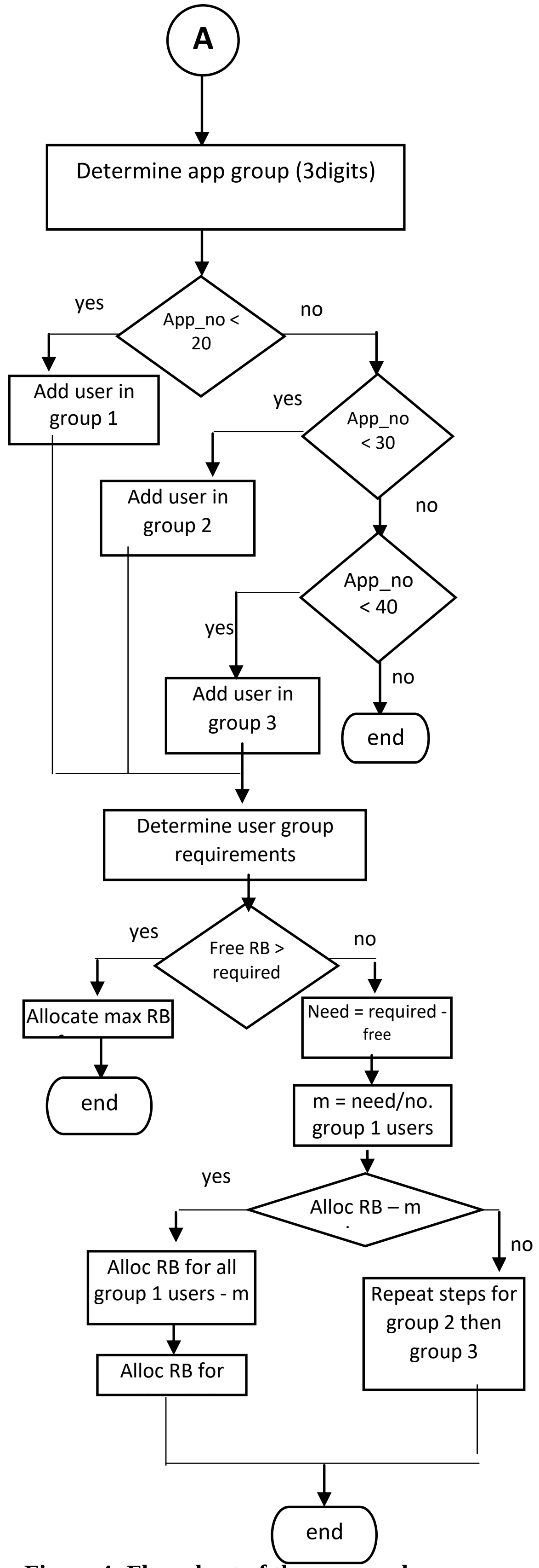


Figure 4: Flow chart of the proposed resource blocks allocation algorithm.

6. Results

To evaluate the performance of our proposed algorithm, we used the discrete-event network simulator NS3 version 3.26 on Ubuntu 14.0.4, installed on DELL Inspiron Laptop which has the following specifications:

- Processor : Intel(R) Core(TM) i3-3217U CPU @ 1.80GHZ
- RAM : 4 Gbyte

We evaluate the algorithm using three propagation models, which are: Friis, Okumura Hata, and Cost231.

6.1 Using Okumura Hata model in Urban:

We evaluated the number of users served using maximum and minimum radio blocks versus the distance between the user and the base station. Then we estimated the allocated radio blocks for each application, in three cases shown in table (5).

Table 5: User rate for video/voice/chat application.

User rate	Video	voice	chat
1:2:1	10	20	10
1:1:2	10	10	20
2:1:1	20	10	10

Figures 5 to 7 show the number of users allocated using max RBs and min RBs in LTE modes 1.4, 10 and 20, versus the distance between the user and the LTE node.

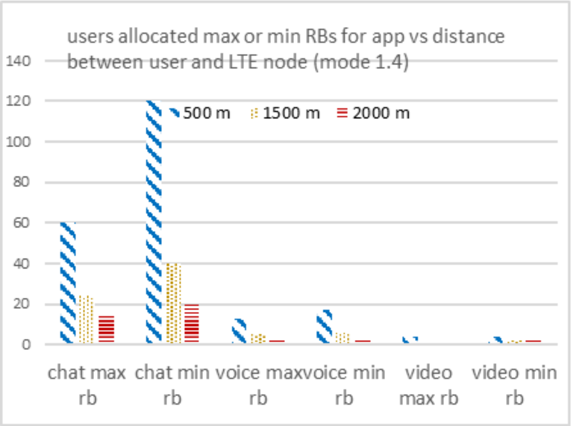


Figure 5: Number of users allocated using max RBs and min RBs in LTE mode 1.4.

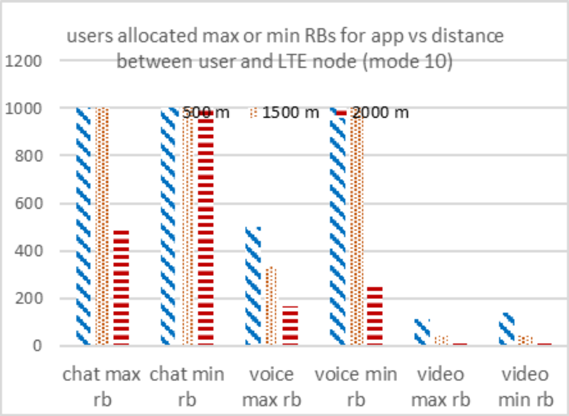


Figure 6: Number of users allocated using max RBs and min RBs in LTE mode 10.

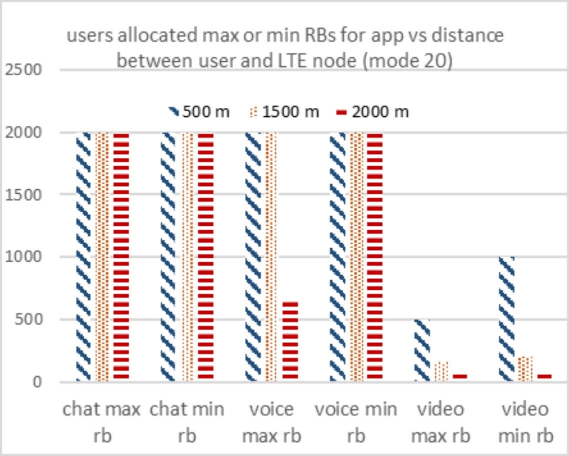


Figure 7: Number of users allocated using max RBs and min RBs in LTE mode 20.

Figures 8 and 9 show the number of users allocated using max RBs and min RBs in mmWave modes 12 and 100, versus the distance between the user and the mmWave node.

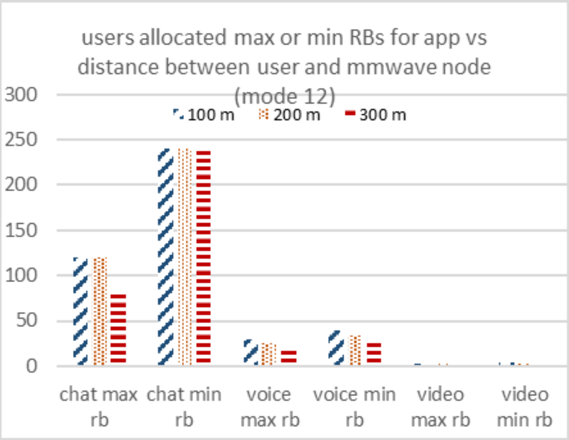


Figure 8: Number of users allocated using max and min RBs in mmWave mode 12.

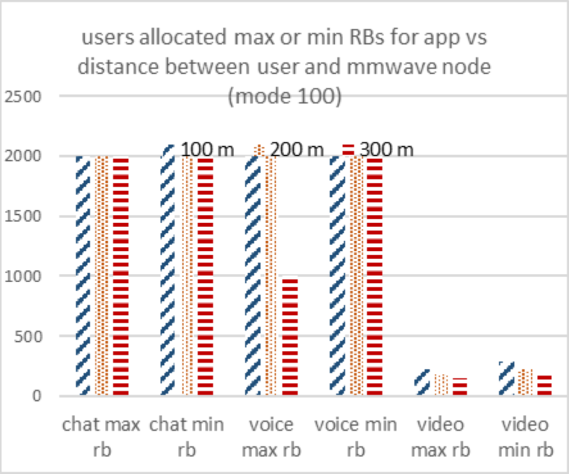
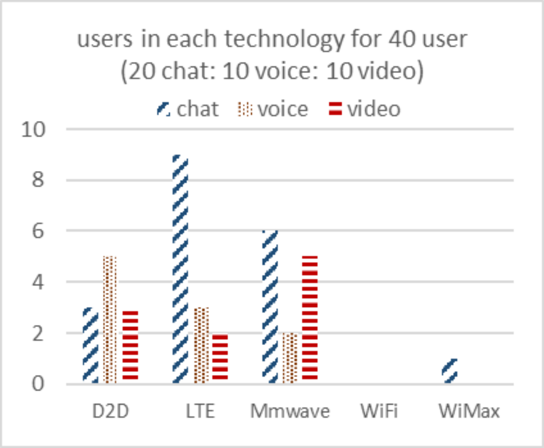
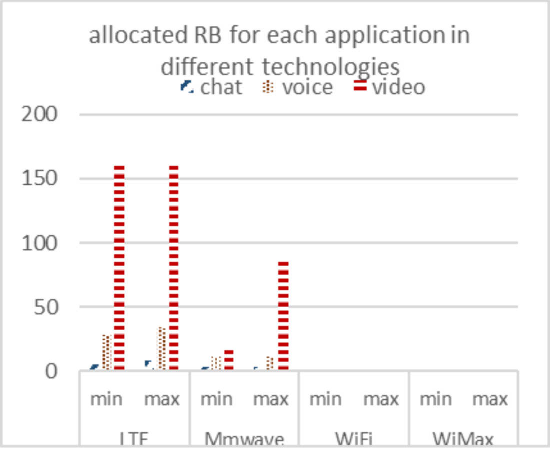


Figure 9: Number of users allocated using max RBs and min RBs in mmWave mode 100.

Figures 10, 11 and 12 show the number of users in each technology and the allocated resource blocks for each application in the three cases of user rates shown in table (5).

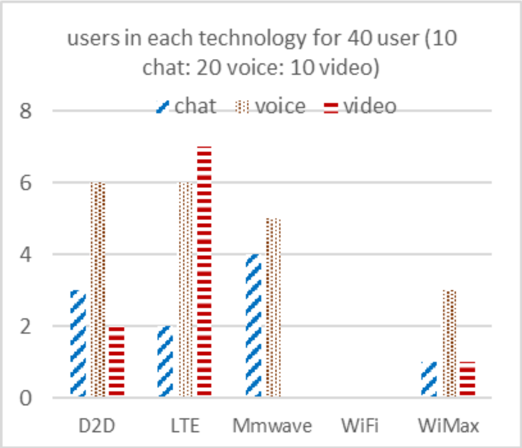


(a)



(b)

Figure 10: (a) Number of user in each technology, (b) the allocated RBs for each application in case of user rate (chat 20: voice 10: video 10).



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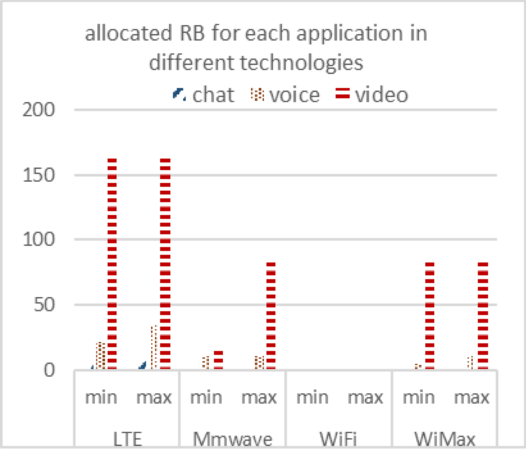
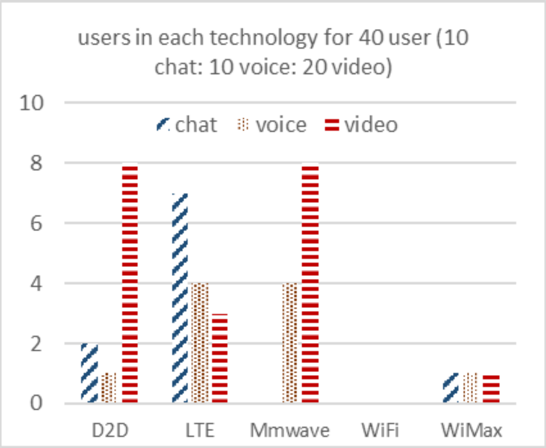
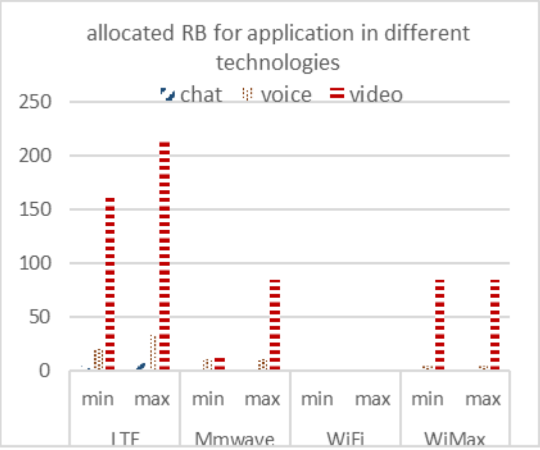


(b)

Figure 11: (a) Number of user in each technology, (b) the allocated RBs for each application in case of user rate (chat 10: voice 20: video 10).



(a)



(b)

Figure 12: (a) Number of user in each technology, (b) the allocated RBs for each application in case of user rate (chat 10: voice 10:video 20).

When we used LTE mode 1.4, we found that the number of voice users decreased from 13 at distance 500m to 3 user at distance 2000m, but this number increased to 500 voice users at distance 500m and to 166 at distance 2000m in LTE mode 10.

In mmWave 12 mode, we served 40 voice users at distance 100m and 26 at distance 300m, but this number increased to 2000 users at all distances in mmWave 100 mode.

6.3 Using Cost231 model:

We estimated the number of users served using maximum and minimum radio blocks versus the distance between the user and the base station. Then we estimated the allocated radio blocks for each application, in three cases shown in table (5).

Figures 13 to 15 show the number of users allocated using max RBs and min RBs in LTE modes 1.4, 10 and 20, versus the distance between the user and the LTE node.

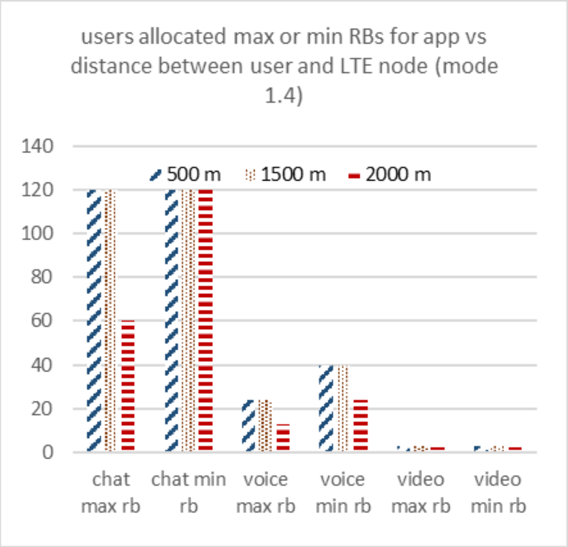


Figure 13: Number of users allocated using max RBs and min RBs in LTE mode 1.4.

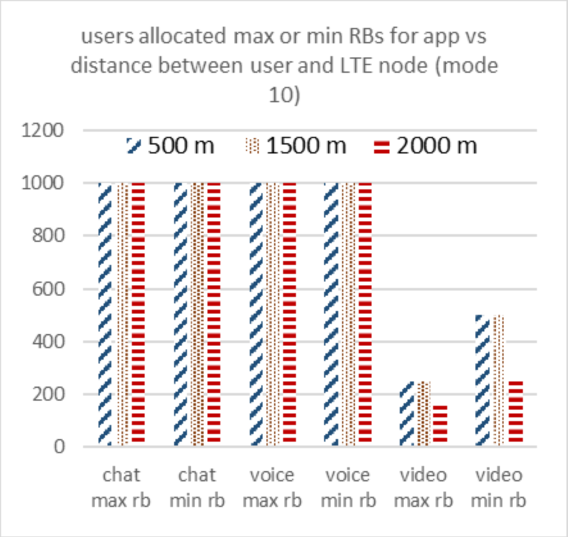


Figure 14: Number of users allocated using max RBs and min RBs in LTE mode 10.

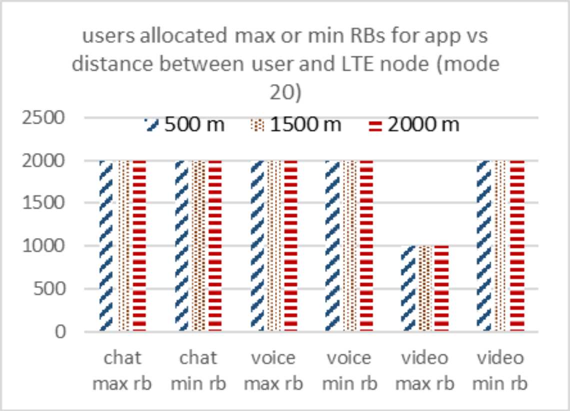


Figure 15: Number of users allocated using max RBs and min RBs in LTE mode 20.

Figures 16 and 17 show the number of users allocated using max RBs and min RBs in mmWave modes 12 and 100, versus the distance between the user and the mmWave node.

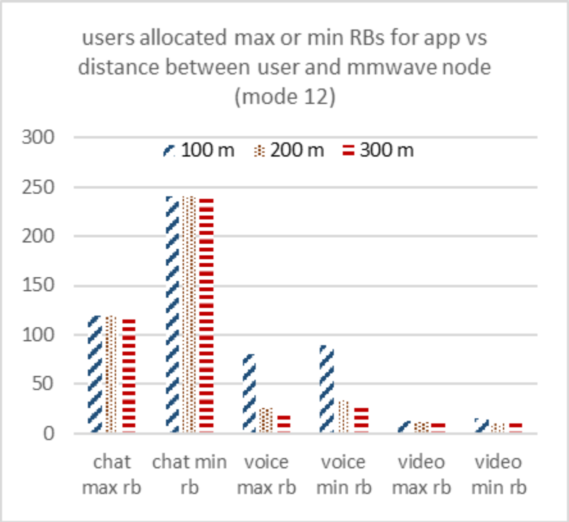


Figure 16: Number of users allocated using max RBs and min RBs in mmWave mode 12.

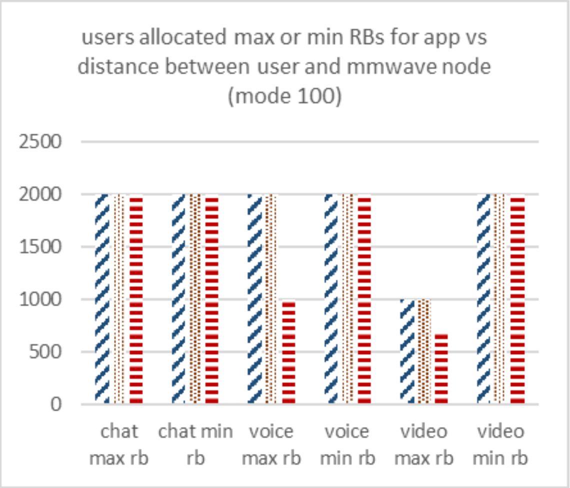
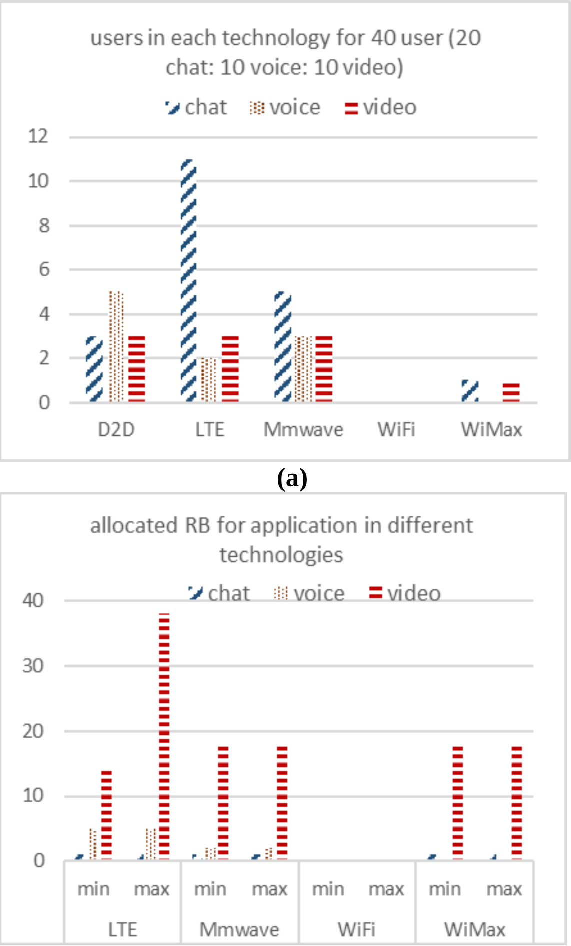


Figure 17: Number of users allocated using max RBs and min RBs in mmWave mode 100.

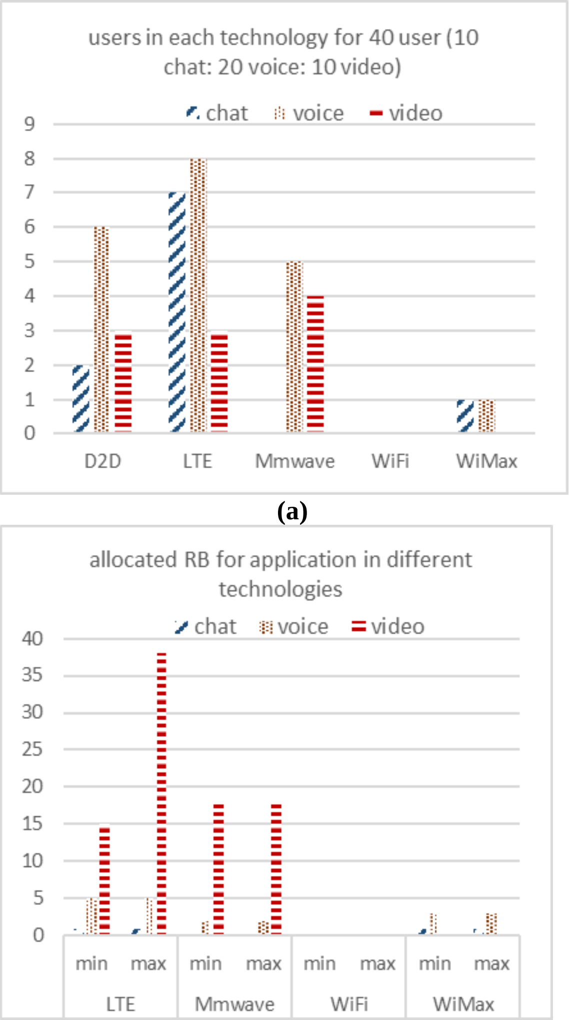
Figures 18, 19 and 20 show the number of users in each technology and the allocated resource blocks for each application in the three cases of user rates shown in table (5).



(a)

(b)

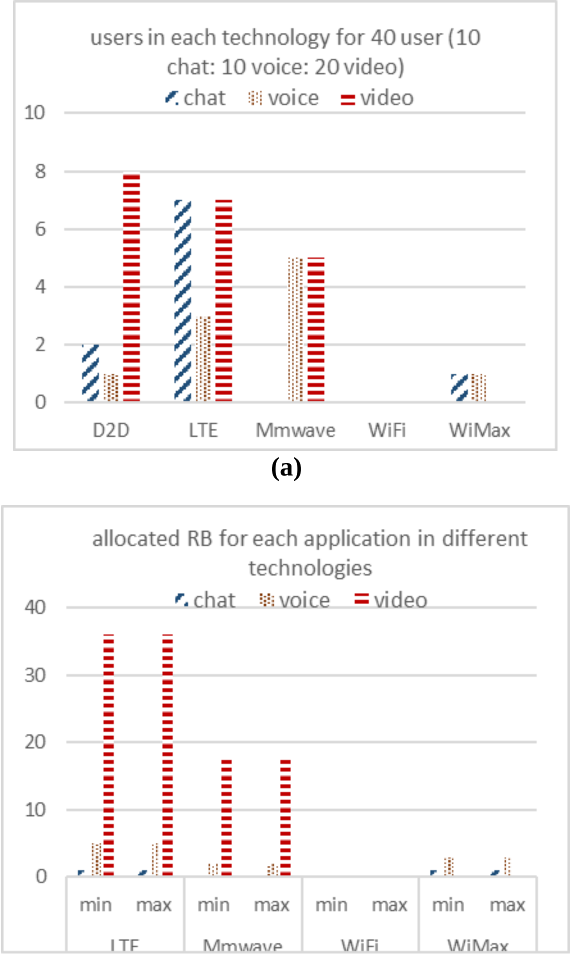
Figure 18: (a) Number of user in each technology, (b) the allocated RBs for each application in case of user rate (chat 20: voice 10: video 10).



(a)

(b)

Figure 19: (a) Number of user in each technology, (b)the allocated RBs for each application in case of user rate (chat 10: voice 20: video 10).



(a)

(b)

Figure 20: (a) number of user in each technology, (b) the allocated RBs for each application in case of user rate (chat 10: voice 10: video 20).

When we used LTE mode 1.4, we found that the number of video users decreased from 3 at distance 500m to 2 users at distance 2000m, but this number increased to 250 video users at distance 500m and to 166 at distance 2000m in LTE mode 10.

In mmWave 12 mode, we served 13 video users at distance 100m and 10 at distance 300m, but this number increased to 1000 users at distance 100m and 666 users at distance 300m in mmWave 100 mode.

7. Discussion

In this paper, we proposed a new resource scheduling algorithm based on application requirements. We estimated the number of users served with maximum radio blocks (RBs), or with minimum RBs for each application. We used three radio propagation models, which are Okumura Hata, and Cost231, to evaluate their effect on the proposed algorithm.

We found that the number of users decreased when the distance from user to the eNode incresaed, because they need more resources.

When we used Cost231 propagation model in LTE mode 1.4, we found that the number of chat users decreased from 120 at distance 500m to 60 user at distance 2000m. But when we used Okumura Hata model, the number of users was only 60 user at 500m and decreased to 15 user at 2000m.

In mmWave 12 mode, we served (10 to 7) video users in Cost231. But this number decreased in Okumura Hata to a value between 4 and 2.

We also estimated the allocated resource blocks for each application in case of 40 users classified in video, voice and chat with different user rates. We found that LTE gives RBs that are between 5 and 8 for chat users, between 28 and 34 for voice, and 163 for video. Since it was 3 for chat, 11 for voice, and between 16 and 85 for video.

Conclusion

In this paper, we studied radio propagation models and resource scheduling algorithm to propose a new radio resource algorithm that takes into account application requirements. We evaluated our proposed algorithm using a proposed 5G network, built using NS3 simulator. We studied the performance of our algorithm in case of served users and allocated resource blocks in each application, using three propagation models which are Okumura Hata and Cost231.

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