ANALYSIS OF COMBINATIONAL RESOURCES ALLOCATION FOR VARIOUS USER EQUIPMENT APPLICATION REQUESTS IN A FEMTOCELL

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Abstract
Growing data requirements due to increase in cell phone usage has led to new generation of technologies such as Long Term Evolution networks used in femtocells. However, users vary in terms of resource block demands due to high bandwidth cell phone applications which are normally limited in a femtocell.
This paper uses two examples for bandwidth analysis per user's cell phone application needs and applies the combinational selection technique to allocate resources. First, it determines the number of resource block requests then the combinational algorithm computes the best users' sequence allocation.
The first example considers when a cell phone is switched on. It utilizes the synchronization signals to search for available resources for connection. These occupy a single slot in a resource block. A scenario of 6 users is considered where the users have the following SINR (Signal to Interference plus noise ratio) values. User 1 has 10 dB, user 2 has 20 dB, user 3 has 15 dB, user 4 has 5 dB, user 5 has 12 dB and user 6 has 18 dB. The combinational sequence is carried out against 4 available resources. The highest SINR group is found to be users: [2 3 5 and 6] who are allocated resources. A second example considers the same six users with different set of data transmission requests. With only 18 available resources, the results are: user 1 is allocated 2 resources, user 2 is allocated 2 resources, user 3 is allocated 5 resources, user 5 is allocated 5 resources and user 6 is allocated 4 resources. These demonstrate that the combinational technique allocates all resource requests types and still prioritizes high SINR valued users.

Key words: SINR (Signal to Interference plus noise ratio), combinations, resource block.

1.0 Introduction
The latest trends in mobile telephony have seen a tremendous growth in data applications on cell phone networks. This has created the need for increased data transmission rates that keep on increasing per users' data requirements (Sousa, Vasco , & Tiago, 2004). Newer cell phone technologies such as Long Term Evolution networks that are used in femtocells have evolved in a bid to improve bandwidth utilization. However, bandwidth is usually limited compared to users application demands, therefore femtocell resources have to be optimized to enable accommodation of as many users' requirements as possible.

2.0 Long Term Evolution Frame Structure
Mobile phone access schemes have evolved over the years starting from the earliest technologies that could only allocate frequency slots to single users as experienced in 1G communication with the use of the AMPS (American Mobile Phone System). These technologies have grown to the latest technologies that have improved bandwidth utilization such as the OFDMA (Orthogonal Frequency Division Multiple Access) (Sudhir B. Lande, December 2012). The OFDMA technology allocates several resource blocks to users dynamically to users hence improving bandwidth utilization (Anritsu, 2009)

Long Term Evolution (LTE) networks make use of a pure IP (Internet Protocol) framework so as to provide voice and data services to the mobile users. These make use of the downlink that can support speeds of up to 100 Mbps and uplink that can support speeds of up to 50 Mbps (Sesia, Toufik, & Baker, 2011).

(a) Femtocells

Femtocells are indoor base stations used in LTE networks to provide network coverage in poorly covered areas inside buildings or indoors. They are also known as Home eNB (HeNB). They are normally configured to accommodate a given limited number of users. (Oyie , Langat, & Musyoki, 2014).

(b) Resource block structure

OFDMA technology splits the frequency spectrum into subcarriers that are assigned to several users in the femtocell dynamically. These are arranged in the form of 12 resource blocks occupying 180 KHz in the frequency domain with each resource block having a bandwidth of 15 KHz (Anritsu, 2009). On the time division duplex, the resource blocks are grouped in terms of radio frames whereby, each radio frame having a span of 10 milliseconds.

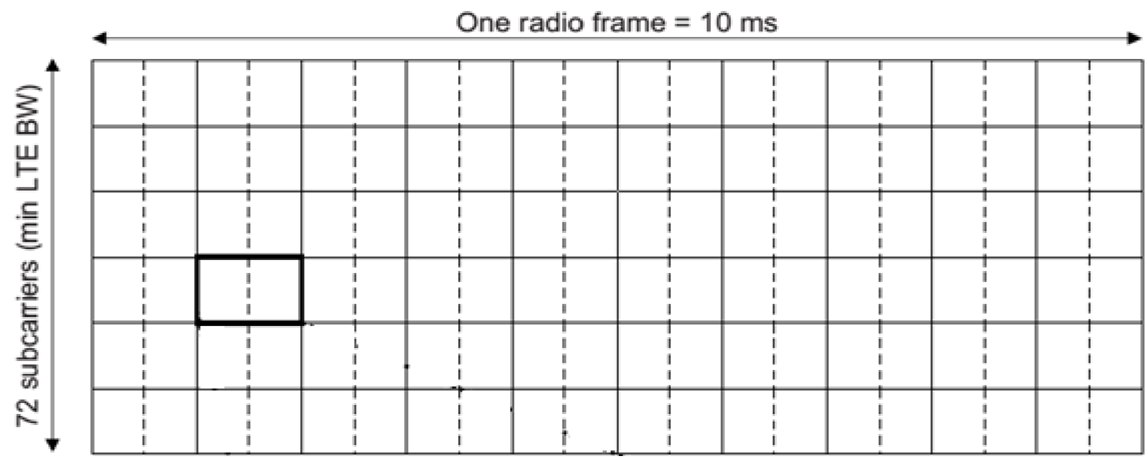

Figure 1: OFDMA resource structure (Sesia, Toufik, & Baker, 2011)

Each resource block has a span of one subcarrier on the frequency domain and 0.5 milliseconds on the time division duplex. The highlighted blocks on figure 1 indicate a sub-frame which is made up of 2 resource blocks and has a time span of 1 millisecond on the time division duplex (Sesia, Toufik, & Baker, 2011). Figure 1 also shows 6 resource blocks with 12 sub-carriers each making a total of 72 subcarriers as shown. Resource blocks are further made up of resource elements. They are used for transmission of various signal types such as signaling, synchronization and broadcast information.

Resource blocks are used to transmit data. The data size transmitted is determined by the modulation scheme used whose standard are tabled in the adaptive modulation and coding scheme for LTE networks as shown in table 1.

Table 1: Modulation Schemes used in LTE networks (Anritsu, 2009)

Modulation Scheme	Bits Per Symbol Transmitted
QPSK (4-QAM)	2
16-QAM	4
64-QAM	6

A given resource block has a span of 12 subcarriers on the frequency domain. Each subcarrier has a size of 15 KHz. On the time division duplex, one resource block lasts for one slot whose period is 0.5 milliseconds. This is because a radio frame on the time division duplex, a radio frame is 10 milliseconds and comprises of 20 slots. Additionally, 2 slots make up a sub-frame on the time division duplex and therefore, a radio frame has 10 sub frames (Sesia, Toufik, & Baker, 2011).

Resource blocks are used for data transmission to and from the user equipment. However, some resource blocks have specific resource elements that are used for additional functions such as: signaling, primary and secondary synchronization (Anritsu, 2009). This paper seeks to analyze these resource requests per application as described in (AlQahtani, 2015).
After determination of resource blocks required, these requests are subjecte d to a combinational scheme with reference to the available resources and the SINR value of each user so compute the best group of resource requests to allocate resources.

(c) Determination of resource block size

A resource block is made up of 12 subcarriers and 7 symbols in the time division duplex using the normal cyclic prefix. The smallest unit is a resource element which has a dimension of 1 subcarrier in the frequency division duplex and 1 symbol in the time division duplex.

The total resource elements are given by:

$$12\ subcarriers\ \times 7\ symbols = 84\ resource\ elements \quad (1)$$

This gives 84 resource elements in 1 resource block for the normal cyclic prefix as described in (Anritsu, 2009).
If the modulation scheme used is 64QAM, whereby 6 bits per symbol are used, this means given that one resource element that has one symbol on the time division duplex frame will transmit 6 bits. Therefore the total bits transmitted by the resource block are given by:

$$84\ resource\ elements\ \times 6\ bits\ per\ symbol\ (in\ one\ element) = 504\ bits\ transmitted\ by\ a\ resource\ block \quad (2)$$

A resource block occupies one slot in the time division duplex (TDD). Two slots make up a sub frame that last 1 ms on the TDD frame

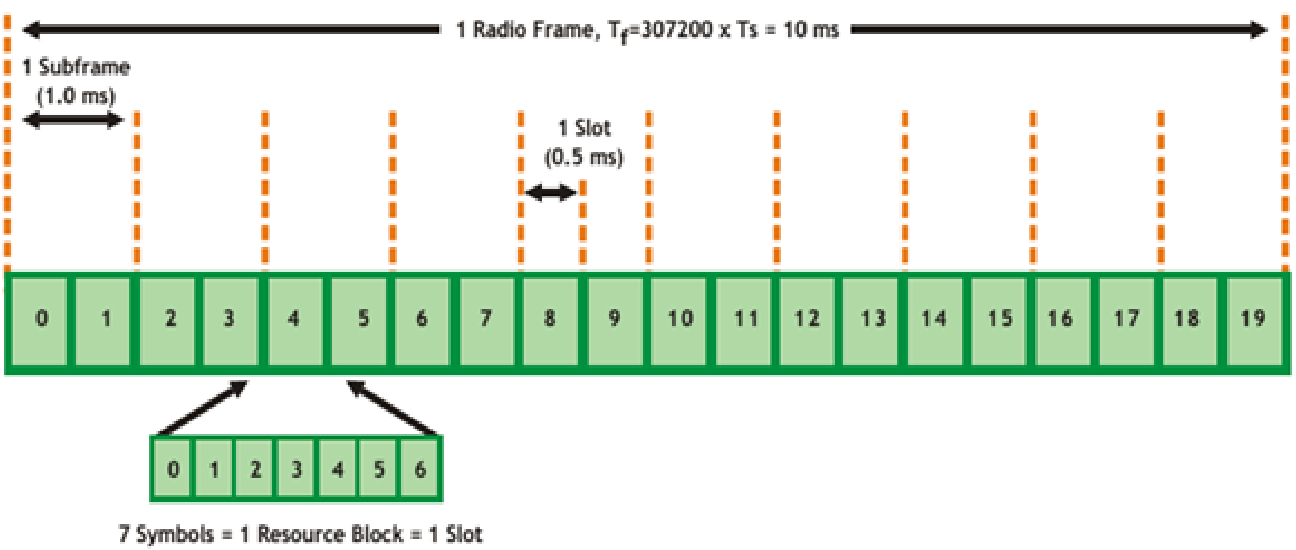

Figure 2: Time Division duplexing radio frame (Anritsu, 2009)

The diagram on figure 2 shows that a slot lasts for 0.5 ms which is equivalent to one resource block which contains 504 bits of data. The data rate per resource block can be calculated as follows:

$$data\,rate\;per\;resource\;block = \frac{504\,bits}{0.5\,ms}$$

$$= 1{,}008{,}000\;bits\;per\sec = 1.008\,Mbps \qquad (3)$$

This gives the data rate of transmission for one resource block. Therefore for higher data rates to be achieved, additional resource blocks have to be allocated.

(d) Determination of resource block requests

i). Allocation for data streaming

Users' mobile equipment has various resource requests for different applications. These are done dynamically with the use of category based admission control schemes that enable applications to request for resources individually and simultaneously (AlQahtani, 2015). This is done dynamically per application. There are applications that require huge amounts of bandwidths such as video streaming and l ive video conferencing while others require fewer of single resources. The number of resource blocks to be allocated for this sequence then has to be calculated using the predetermined value of a resource block.

ii). Allocation for synchronization sequence.

This is a scenario where the cell phone seeks to be connected to the femtocell. The cell phone carries out a cell search and the femtocell responds with the physical layer identity of the cell. This is done using the Primary Synchronization Signal (PSS) and the Secondary Synchronization Signal (SSS) that occur at two intervals in the radio frames (Sesia, Toufik, & Baker, 2011). Figure 3 shows that the resource block at slot '0' and slot '5' carry these signals. This means that only one resource block is required to carry out this sequence.

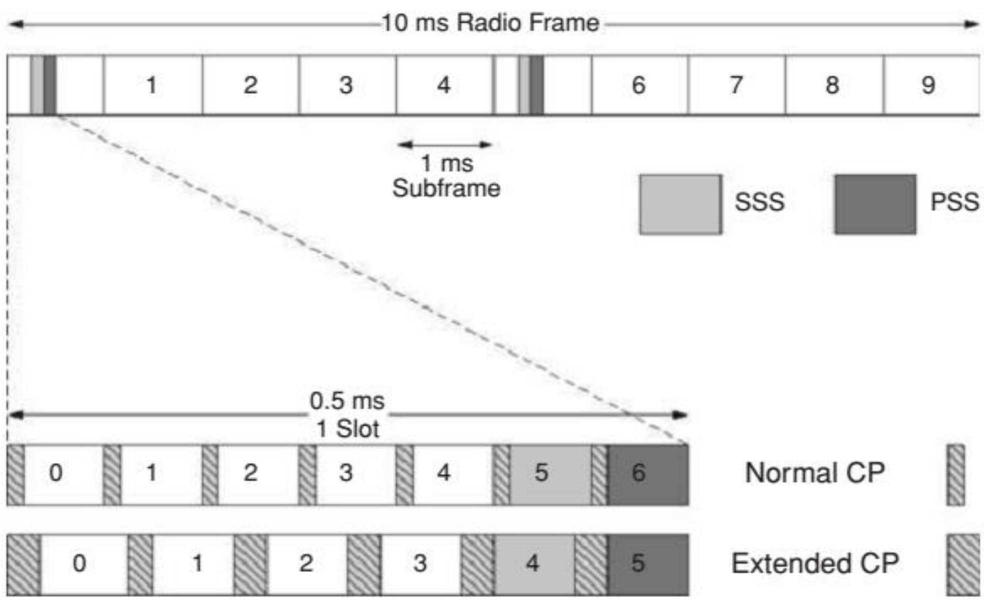

Figure 3: The PSS and SSS in the radio frame structure in the TDD frame (Sesia, Toufik, & Baker, 2011).

3.0 Combinational Allocation Sequence

This is a sequence that has been presented in (Macharia, Langat, & Musyoki , 2017) whereby once users' resources requests have been computed and their SINR values are given, the available resources in a femtocell are then determined. Then, a combinational sequence is thereby carried out to determine the best group of users based on the highest SINR total group of users' requests (Ramprasad , Solaiman , & Roshanak , 2015). It bases on the combinations formula as shown by equation 4 (Richard , 2010 Vol 5.).

$$^{n}C_{x} = \frac{n!}{x!(n-x)!} \qquad (4)$$

where

$^{n}C_{x}$ refers to the different number of arranging 'n' items in a space of 'x' items without regard to order.
n! refers to the factorial of n
x! refers to the factorial of x
(n-x)! refers to the factorial of (n-x)

These requests can be single requests per user or multiple requests per user depending on the category based call admission control that allows mobile applications to request for resources dynamically and simultaneously (AlQahtani, 2015).

4.0 Results and Discussion

In this paper, two scenarios of users who are requesting for resources inside a femtocell will be used to analyze the scenarios that determine the number of resources required by a users' cellphone.

a) Example 1

An example of six users in a femtocell is hereby considered. The users have their individual SINR values as shown in table 2.

Table 2: Users' SINR values present in a femtocell at example 1

EXAMPLE 1	
USER	SINR VALUE (dB)
1	10
2	20
3	15
4	5
5	12
6	18

These users have switched on their cell phones and are requesting for resources for connection in the femtocell. This is usually carried out by primary and secondary synchronization signals that are broadcasted in pairs in every 5 milliseconds. On the radio frame, these two resource blocks occur in pairs and normally occupy a single slot inside a resource block according to (Sesia, Toufik, & Baker, 2011). Therefore, this means that one resource block is required per cell phone for synchronization of the cell phone inside the femtocell. Therefore the allocation sequence therefore considers only one request per user.

From here, the combinational sequence is hence carried out using the consideration of one resource block per user. Given that the available resources in the femtocell are 4. The sequence generated is as shown by equation 1.

$$^{6}C_{4} = \frac{6!}{6!(6-4)!} = 15 \qquad (5)$$

The above sequence gives 15 different ways in which the allocation can be done to the users' individual requests. These combinations are then ranked in order of ascending SINR totals for each group and the highest SINR total group selected. For this example, the highest SINR total is 65 dB belonging to when these users' SINR totals are added: [2 3 5 6]. Therefore using this sequence, the users can then be given priority in terms of allocation of resources for synchronization during the femtocell search process. Similar work has been presented in (Macharia, Langat, & Musyoki, 2016)

b) Example 2

Another example of users in the femtocell is considered in this paper. During this interval, the users have been connected to the femtocell and are now requesting for resource blocks for data transmission. This according to the category based admission control can be done simultaneously by the phone applications. Hence, multiple resources are requested in this instance. A similar example has been presented in (Macharia, Langat, & Musyoki , 2017) whereby, a user's equipment requests for more than one resource and combinations is done dynamically against the available resources in the femtocell. The user's request is done as per the best SINR combination of the requests.

In example 2, the main aim is to evaluate instances in which a user's cellphone is allocated additional resources. The same 6 users who are now connected to the femtocell have multiple applications that require data resources as shown in table 3:

Table 3: Users' bandwidth requirement in the femtocell

User	Bandwidth Requirements
1	3 Mbps
2	2 Mbps
3	5 Mbps
4	3 Mbps
5	5 Mbps
6	4 Mbps

These requirements have to be computed from multiple cell phone applications requesting for resources, so as to determine the number of resource blocks required. Given that a resource block has a bandwidth of 1.0008 Mbps as calculated in equation 3, the above requirements can then be calculated against this pre-calculated value to determine each requirement. From the computation of the bandwidth size of a resource block, it can be seen that the above requests require more than one resource block (RB). This is calculated as follows:

For user 1, the resource blocks required are:

$$\text{resource blocks required} = \frac{3\,Mbps}{\substack{1.008\,Mpbs \\ (for\ 1\,RB)}} = 2.976\,RBs \quad (6)$$

This gives 3 full resource blocks required for user 1. For the remaining users, their resource blocks required for communication are further computed in a similar manner and shown in table 4.

Table 4: Users' resource blocks requirements determined from their bandwidth

User	Bandwidth Requirements	Resource blocks required.
1	3 Mbps	2.976 ≈ 3 full RBs
2	2 Mbps	1.984 ≈ 2 full RBs
3	5 Mbps	4.961 ≈ 5 full RBs
4	3 Mbps	2.976 ≈ 3 full RBs
5	5 Mbps	4.961 ≈ 5 full RBs
6	4 Mbps	3.968 ≈ 4 full RBs

From here, with the users' resource blocks requests known, the method can now proceed further to compute the possible combinations of all the requests against the available resources so as to determine the highest SINR group of users to allocate resources for communication.
Given that the available resources are 18, example 2 can be outlined as shown in table 5.

Table 5: Summary of user's resource requests and their SINR values in example 2

EXAMPLE 2		
USER	REQUESTS	SINR (dB)
1	3	10
2	2	20
3	5	15
4	3	5
5	5	12
6	4	18
Available resources = 18, requested = 22		

When combination is carried out, the best allocation sequence is computed to be:
[1 1 2 2 3 3 3 3 3 5 5 5 5 5 6 6 6 6]
The SINR total for this group is 267 dB.
From the outline of the allocation sequence, it is found that user 4 has been left out. Therefore with application of the fairness scheme, a resource is reallocated from user 1 to user 4 so that all users can be able to communicate. The new sequence of allocation would therefore be as follows:
[1 2 2 3 3 3 3 3 4 5 5 5 5 5 6 6 6 6]. The new SINR total is lowered to 262 dB.

c) Fairness Scheme

This is a scheme that has been analyzed and applied in (Macharia, Langat, & Musyoki , 2017), to consider users who have been left out of the combinational allocation sequence. The algorithm checks on the low SINR user left out, if there is, a resource is re-allocated from the next low SINR valued user to the user who has been left out so that he/she can now communicate. In this case, the scheme lowers the SINR total by a low value such as 5 dB in this example but ensures that all users communicate. It is just a slight compromise on SINR.

5.0 Conclusion

This paper seeks to analyze and calculate the resource blocks required per user in a femtocell first, so as to determine the number required per user to be computed against the available resources for the best SINR allocation sequence to achieve high throughput in the femtocell.

It starts with a first exampled by analyzing the low bandwidth requirement scenario where users are requesting for synchronization and connection. At this point, not all users can be connected since available resources are fewer but also the synchronization occurs in two slots in a radio frame hence only one resource block is required for this sequence at a given instance. The best SINR users are allocated connection resources at this instance.

A second instance is considered later where all the 6, having been connected in the femtocell, they are requesting for data resources. These requirements are computed against the predetermined calculated value of a resource block bandwidth and it is determined that they require more than one resource. The requirements of each are determined and combinations computed for each thereafter. The allocation sequence is then done against the available resources. The user left out is reallocated a resource using the fairness scheme that had been earlier analyzed as a viable consideration for the low SINR valued user without extensively compromising on the SINR value.

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