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Research paper

Resource Allocation Algorithms For Enhanced Performance In Wireless Virtualization Networks

Md. Nazmus Saadat*, Husna Osman, Munaisyah Abdullah, Rasheed Mohammad Nassr, Hassan Dao, Megat F. Zuhiri

Universiti Kuala Lumpur, Malaysia.
**Corresponding author E-mail:mdnazmus@unikl.edu.my*

Abstract

Wireless Virtualization Networks (WVN) is emerging in research community for the spectrum management and efficiency reasons with the shared wireless radio resources like radio frequency (RF) and its infrastructure. The main idea is slicing and sharing it amongst the participating service providers. In this paper, we propose radio resource allocation (RRA) mechanism in settings of WVN to enhance overall network efficiency in next generation networks. The idea considers of course wireless channel quality of the requesting and existing nodes like along with multiple essential and significant factors during decision cycle in response to every allocation request. For simplicity at this stage of research, we categorized user types into higher and lower priority users and implemented our solutions which can be adjusted in later stage. Here, we consider network performance by use of simulation and show that our proposed system outperforms existing works. This would benefit both mobile network operators (MNO) and wireless service providers (WSP) in the WVN environment.

Keywords: *Software Defined Networks; Wireless Virtualization Networks; Radio resource; Resource allocation algorithms; Network performance.*

1. Introduction

This document can be used as a template for Microsoft Word versions 6.0 or later. Do not submit papers written with other editors The 5G has been in discussion and focus for some time now amongst research communities for various transformations of the current networking and communication platforms. One of the most important aspect is, it is moving towards virtualizing almost everything in information and communications technologies (ICT) for making robust, dynamic, cost effective and manageable that seems to be the starting of new ICT era in recent history. As such, for wireless communication domain, it is anticipated that it would have provision for a generalized core for multiple types of radio access technologies (RAT), machine type communications (MTCs), multiple types of networks and network service providers [2].

There might be two options for the system to consider. First is that the base station (BS) receives the allocation request along with all layers' required parameters and then the BS will pass all the info to the computing module of the resource allocation systems. However, the downside of this option is that the computation load and data transmission load would be much high and except transmission and reception of data. This is why the second option, WVN, is now considered to be a prime effective solution for 5G which is to keep software stacks of the required layers in the computing part of the RA in virtualized way creating WSPs and MNOs in conjunction with software defined networks (SDN), so that the extreme modification can be immediately done to the BS stacks and can take the benefits of various technologies in virtualized form rather than combined hardware-software form. For example, if a cross layer mechanism might be used to manage more the resources efficiently. This is due to the technologies like SDN or Network Function Virtualization (NFV) which is foreseen as the base infrastructure for Internet of Things (IoT) and 5G in near future [3][4] but virtualization and resource sharing mechanisms often results in instability of communication [5]. However, this can be improved by tackling delay performance to maintain overall user-experience. One of the delay types that happens is in the base station when number of users are large during the process of the resource request from user mobile devices. The wireless environment is one of the major reason for the level of quality the user might get due to the channel quality [1], besides, how the requests are processed also affects it. We present an efficient and intelligent solution to improve the overall system delay efficiency for this type.

The future of IoT heavily depends on 5G platforms where hundreds and thousands of devices might be connected with its' own network resource requirements. And managing the allocation of resources specially in wireless scenario might be very challenging. As spectrum is limited and the number of requesting devices for communication would need a particular focus to handle well, it would need optimized radio resource allocation mechanism which is usually computationally expensive for a fully optimized implementation. In this aspect we would present a network infrastructure combined with allocation algorithms to manage radio resource that should be cost savvy and more effective. The structure and major components of the systems are shown in Fig. 1.

Recently there have been number of state of the art research in the literature. For example, [7] presents algorithms Bw-Risk-Ratio that considers best virtual topology to provide higher number of user access but the energy efficiency is not address. Authors in [8] proposed resource allocation algorithms for virtualized networks to reduce infrastructure cost, but the application is in the are of sensor networks. [9] presents an extensive framework for QoS-oriented modelling that might not guarantee optimized output always. However, our system guarantees that there will be always an optimal solution and also provides with higher delay- performance.

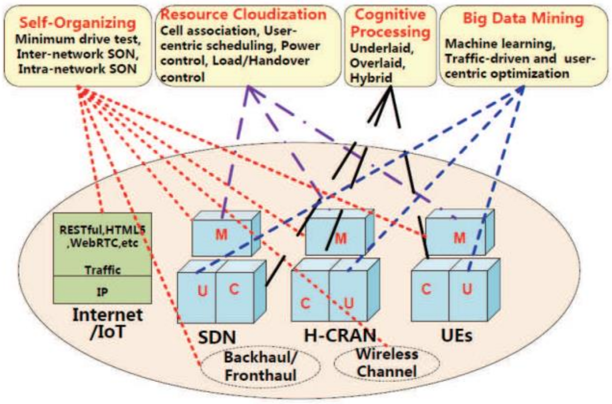

Fig. 1: Different components and major functionalities of next generation networks [14].

2. System Model & Problem Formulation

Fig. 1 shows the conceptual model of WVN where the infrastructure service provider (InSP) provides the only physical wireless radio networks consisting of users who request for wireless access and base station would be responsible to accept the service request and trigger for the allocation cycle as shown. Other parts are considered to be virtualized. In this context, we propose an adaptive and optimized resource allocation algorithm that would match the environment discussed earlier. The system considered have user equipment (UE)/subscriber stations (SS) communicating directly to the BS in a point to multipoint fashion shown as in Fig. 3. This

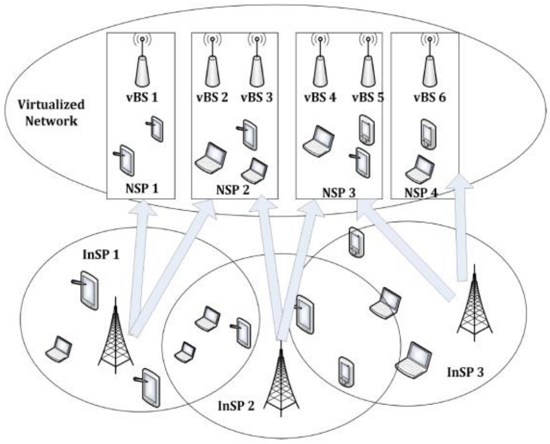

Fig. 2: Conceptual framework for Wireless Network Virtualization [2].

part is shown in the next figure along with the whole request/response cycle as depicted in Fig. 4. It represents the inner processes in the context of WVN.

As in [6], WVN heavily depends on physical wireless technologies like 3GPP-LTE, Wi-Fi and WiMAX networks as well as RANs like code division multiple access (CDMA) and orthogonal frequency division multiple access and its variants, we considered OFDMA to be used for the proposed system which is used in WiMAX and LTE which are considered already to be virtualized as in [3]. The Fig. 3 shows a common setup of such scenario that can be applied to WiMAX/LTE, however, at this phase of research, in this paper, we focus on the downlink optimization.

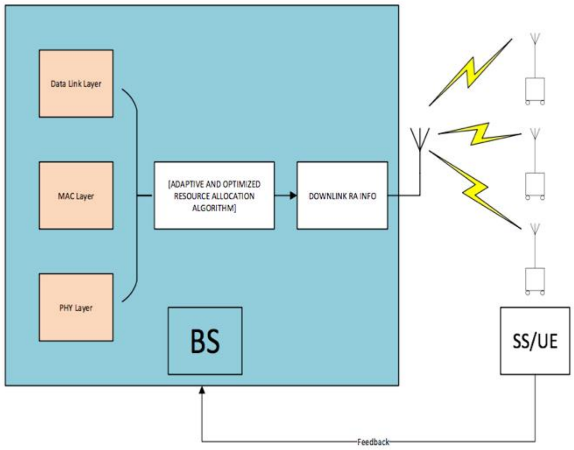

Fig. 3: Cross Layer Solution model for OFDMA based resource allocation in connection oriented networks.

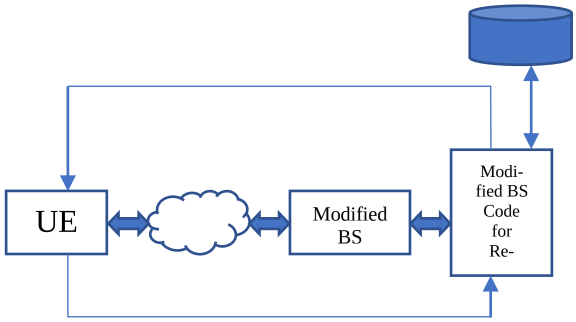

Fig. 4: Cross Layer Solution model for OFDMA based resource allocation in connection oriented networks.

Table 1 refers to some of the major parameters used to simulate the proposed system. The WiMAX 802.16e virtualization is considered and based on the standard system parameters. Problem formulation of the proposed system should be provided at this stage.

Mathematically, the optimization problem considered here can be formulated as from Zukang S. et al [2] in (1):

$$\max_{p_{k,n}\rho_{k,n}} \sum_{k=1}^{K}\sum_{n=1}^{N} \frac{\rho_{k,n}}{N}\, log_2\left(1+\frac{p_{k,n}h_{k,n}^2}{N_0\frac{B}{N}}\right) \tag{1}$$

Subject to

$$C_1: \sum_{k=1}^{K}\sum_{n=1}^{N} p_{k,n} \le P_{total}$$

$$C_2: p_{k,n} \ge 0 \; for\ all\ k,n$$

$$C_3: \rho_{k,n} = \{0,1\} \; for\ all\ k,n$$

$$C_4: \sum_{k=1}^{K} \rho_{k,n} = 1 \; for\ all\ n$$

$$C_5: E[T_k] \le \tau_k$$

Here,

- K is the total user number,
- N denotes the total subchannel number,
- B and P_{total} are the total bandwidth and power.
- $p_{k,n}$ denotes the power that is allocated for user k on the sub-channel n

- $\rho_{k,n}$ is to be either 0 or 1, that indicates if user k is using sub-channel n.
- fading and channel gain of user k on subcarrier n is $g_{k,n}$, having AWGN or additive white Gaussian noise, $\sigma^2 = N_0 \frac{B}{N}$, and N_0 denotes noise power spectral density [1]
- and its channel to noise ratio for the subchannel, $h_{k,n} = \frac{g_{k,n}^2}{\sigma^2}$
- user k receives the SNR on subcarrier n, $\gamma_{k,n} = p_{k,n} h_{k,n}$
- C4 shows each subchannel can be used by one user only.
- user k has the channel capacity of R_k which is given below:

$$R_k = \sum_{n=1}^{N} \frac{\rho_{k,n}}{N} log_2 \left(1 + \frac{p_{k,n} h_{k,n}^2}{N_0 \frac{B}{N}} \right) \quad (2)$$

Users bits are modulated in BS into N M-level QAM and then combined using IFFT into OFDMA symbols [10], [11], the sub-channel-to-noise ratio be,

$h_{k,n} \geq 4$ and BER$\leq 10^3$ [12],
and, $BER_{M\text{-}QAM}(\gamma_{k,n}) \approx 0.2exp\left[\frac{1.6\gamma_{k,n}}{2^{\gamma_{k,n}}\text{-}1}\right]$.
then, solving for $r_{k,n}$, we have

$$\boldsymbol{R_{k,n} = log_2 \left(1 + \frac{\gamma_{k,n}}{\varphi} \right)},$$

where, $\varphi = \left(\frac{\text{-ln}\,(5BER)}{1.6} \right)$, which is a constant (SNR gap) and $H_{k,n} = \frac{h_{k,n}^2}{N_0 \frac{B}{N}}$.

For simplicity, we considered users mainly of two types, which are high priority users and general users (low priority). Thus if the users are of type high priority users, the rate calculation would be,

$$R_k = R_k + \frac{B}{N} log_2 \left(1 + \frac{pH_{k,n}}{\varphi_{high}} \right) \quad (3)$$

if the user is of low priority, the rate calculation will be

$$R_k = R_k + \frac{B}{N} log_2 \left(1 + \frac{pH_{k,n}}{\varphi_{low}} \right) \quad (4)$$

Equation (3) and (4) is used to calculate rate for the user during allocation cycle. Typically, there might be various kinds of services or user types and that can be handled by tuning the equations as well. However, the core operations on radio resources are as followings:
Assume that,
A = {1, 2, …, N}, the subchannels in set.
S(A)=size of A.
N = total number of subchannels.
NR =Remaining channels
Ri = set of user requests, i=1 to M
Ri = {R1, R2, …, RM}.
Last request=RL,
q = the request of user k for rate, q
= the set for user k consisting of allocated subchannels
Z=Size ( ) = total subchannels of .
Rk = the total allocated rate/capacity for k
RLastone= last request with positive demand>0
The steps of the allocation are as follows:
Start
Initialize:

1. Sort the users as per the delay bound and priority information received from MAC layer in ascending order, and start processing from top to bottom. Get the number of subcarriers required to serve the current request: assign nk = Z, for every user and Rk > q and nk is minimum, for all , where nk is the count.
2. Repeat process 1 and 2 where total of > S(A). Ri = {Ri – RL}. RL not accepted, as it is R while S(A) < = . Otherwise, NR= size of (A) –
3. Run KMA [13] for getting optimized for every admitted k having the number of the subcarriers in step 1, S(A) is unchanged at this stage.
4. For all admitted k and Rk > q, update A, with (A - { }); R with (R - q)
5. Ri=R(i+1) if Ri≠RL
6. When S(A) ≠ 0, R ≠ {}, nk = nk + 1. Otherwise, if NR = 0 then R = R – RLastone.
7. Repeat 1 - 7 while size of (A)> nk
8. Assign for each element in using Greedy waterfilling
9. Call module rate_allocation(selected_subcarrier)
End
//module rate_allocation pseudo code
rate_allocation(selected_subcarrier)
{//start
if user priority == high{
Use equation (3) to calculate rate assignment
Update system of the assignment
}
else if user priority == low{
Use equation (4) to calculate rate assignment
}
//multilevel priority is achievable, but not considered at this stage of our research implementation

This processes are realized in simulator and related results are extracted for comparison and analysis that will be discussed in the next section.

3. Simulation and Results

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We chose QualNet to simulate the network components in codes to perform as per our proposed design. We have considered the effect when our simulations run for different simulation time/duration. As per our proposed solution, the longer the simulation runs better the effect becomes providing an overall network performance specially in terms of delay. The number of participating nodes and the traffic load also play significant role on the output. We will present the delay resulting from the simulation experiments in Fig. 5 and Fig. 6 (zoomed version for clearer evaluation is give in Fig. 7 and 8).
First of all the comparison is for 10 nodes. But the variation is very less as it is expected. Because the participating nodes are only 10 which creates very less traffic and less pressure on the systems.

Table 1:. Major simulation parameters (wimax based) applied in the wvn

System Parameters	Respective Values
Total Bandwidth	20 Mega Hertz
FFT=Total Subcarriers	2048
Data Subcarriers	1440
Pilot Subcarriers	240
Guard Subcarriers	368
Maximum (BS) Transmission Power	50 Watt
CP	1/4

Then we increase the number of nodes and also the traffic from 20 towards 100. In the beginning the effect is found not to unexpected. However, whenever the load is 100 and simulation time is also considered for long runs, the effect is very clear and positive.

It really outperforms [1] showing almost 6 times better delay performance as shown in the second graph.

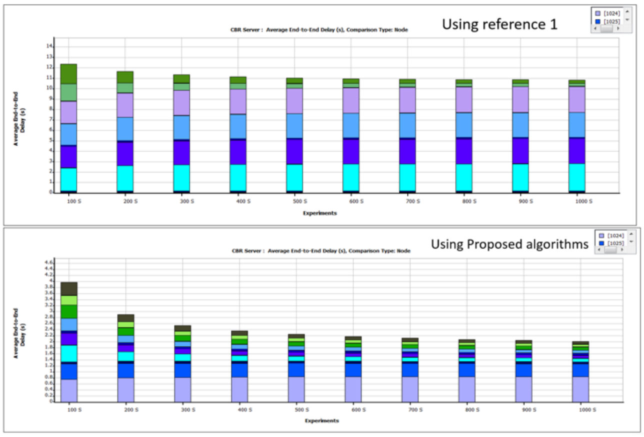

Fig. 5: Effect of the algorithms for 10 nodes only (Zoomed version provided after the reference section).

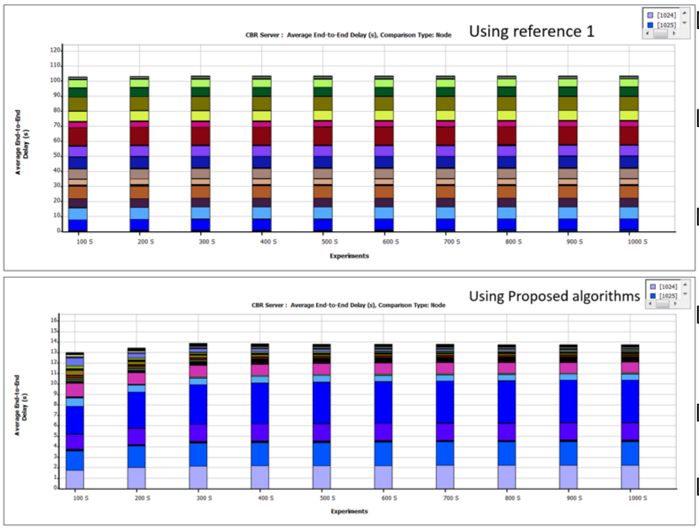

Fig. 6 : Effect of the algorithms for 100 nodes (Zoomed version provided after the reference section).

4. Conclusion

This paper focuses on efficient resource allocation algorithms for WVN so that overall system efficiency is enhanced. We emphasize on improving delay specially because forthcoming 5G requires very highly efficient delay performance due to the required types of services to be provided. Also our solution is readily implementable for WiMAX based Network Federation [15] idea where multiple based stations will share the spectrum under certain service level agreement among the vendors. However, we considered only for downlink of the system, but we are in progress for the uplink and would soon be able to look into it in more details and kept it as near future work.

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Appendix

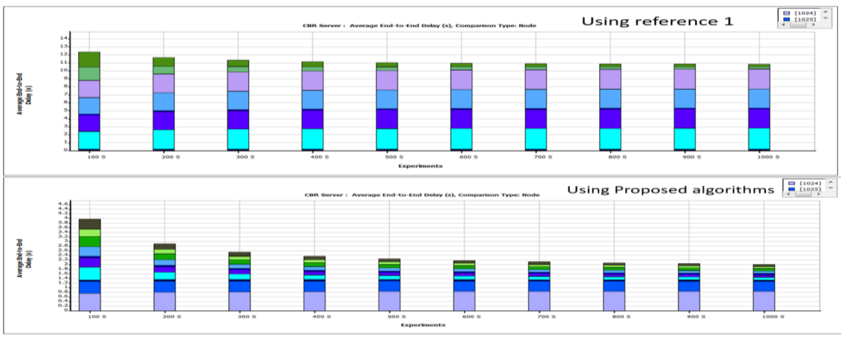

Fig. 7: Zoomed version of Fig. 5

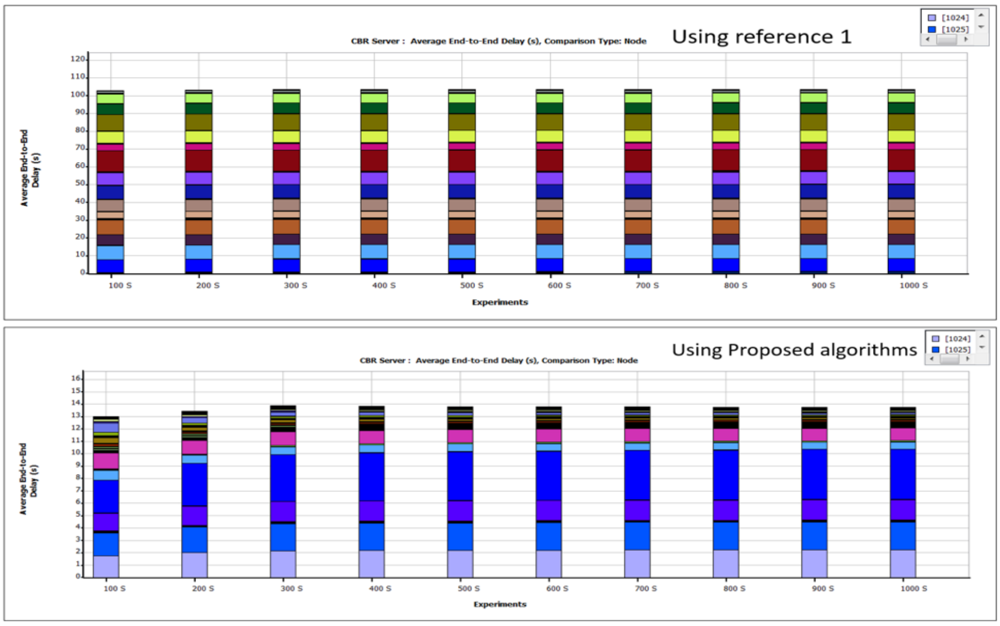

Fig. 8: Zoomed version of Fig. 6