SDN/NFV based Secure SCMA design in SDR

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***Abstract*—Due to increased mMTC devices in 5G, OFDMA has not been a solution for resource allocation in SDR. Therefore; SCMA which is one of the code domain NOMA has been using in such overloaded cases. As distinct from OFDMA, it uses also the constellation diagram as an addition to frequency and time domains in resource mapping to the mobile user equipment. The current studies do not consider UE prioritization while code allocation in SCMA is believed to enhance QoS of the whole topology. Moreover, due to the nature of SCMA, protecting the privacy of UE has become harder than conventional allocation strategies. The implementation details of secure SCMA does not consider by handling low OPEX/CAPEX. Therefore, in this paper, we introduce a novel SDN/NFV based SDR by handling these 5G paradigms into the same platform to overcome the aforementioned challenges. With SDN, we newly define a QoS metric; i.e. received power over overloading of SDR, for UE prioritization such as Micro and Macro UE in an SDR. With NFV, SDR can have two virtual roles shown to UEs by Macrocell and Microcell virtual network functions. With SDR, the SCMA code allocation is performed according to defined Macro and Micro codes are taken from generated codebooks. Afterward, it performs the asymmetric encryption algorithm to provide security of code allocations and the privacy of the user. According to performance evaluation; when overloading is 150%, the Micro UEs have 10x better BER than Macro UEs where the QoS is acceptable for the whole topology.**

***Index Terms*—SCMA, SDN, SDR, NFV, NOMA, 5G**

I. Introduction

In 5th Generation (5G) New Radio (NR), the global mobile traffic is expected to extremely increase by different contents available in the cloud market. These contents vary as enhanced Mobile BroadBand (eMBB), Ultra-Reliable Low Latency Communication (URLLC), and massive machine-type communications (mMTC) [1]. Especially for mMTC, it is estimated that there will be 29.3 billion networked devices by 2023 with rapid enhancements in computing technology. This will result in a 1000 times increase in capacity while considering the number of device per cell [2]. However; this overloading cannot be handled by conventional 4G spectrum sharing methods, i.e. orthogonal multiple access (OMA) such as orthogonal frequency domain multiple access (OFDMA). Therefore, 5G proposes the non-orthogonal multiple access (NOMA) which enables to share spectrum in also power, code, or multiplexed domains as an addition to frequency and time domains [3].

Sparse code multiple access (SCMA) is one of the NOMA techniques and it is recommended to use especially for resource allocation of mMTC with overloading capability [4][5]. It replaced codebooks and resource mapping instead of baseband modulation. Here, a user equipment (UE) can transmit data over multiple physical resources with a code allocated itself from codebook. Each UE has different codes where the constellation mappings are also used in addition to frequency, time, or code domain resources [6]. In the literature, there are a few studies that focus on SCMA codebook design by evaluating Bit Error Rate (BER) [7], [8]. It has been shown in [9] that UEs can be prioritized with different codebooks. However, allocated codes from codebook can result in different BER performance for different user and these researches have not been considering user prioritization for code allocation which would enhance whole system Quality of Service (QoS)[10][11].

Moreover, the security of data transmission is another urgent requirement of 5G. SCMA becomes protecting the privacy of user data more challenging due to the broadcasting codebook in the radio domain. Because of SCMA nature, the user receives multiple data from multiple resources in different codes; and then, if it is a malicious user, it can not easily decode such data without codebooks and mapping matrix. Because of having privacy issue, there have been only a few papers in the literature [12]. They have not been giving implementation details of secure SCMA by considering the 5G deployment requirement such as handling low OPEX/CAPEX[13].

SCMA can easily be implemented to OFDM-based systems [7]. This requires cost-efficient deployment under the heterogeneity of wireless access networks (4G&5G). We believe that introducing the heterogeneity in the same platform with low OPEX/CAPEX can only be handled by using some new paradigms together: network function virtualization (NFV), software defined radio (SDR), and software defined network (SDN) [14][15]. Here, SDN is responsible for the orchestration of network elements by decoupling data and control plane to consider end to end transportation, routing and switching with guaranteed QoS. SDR is a new radio that enhances spectrum sharing with an efficient resource utilization and it has also communication capability with SDN/NFV. It is responsible for the issues executing in protocol stack such as modulation, signal processing, data encryption/decryption. NFV decreases

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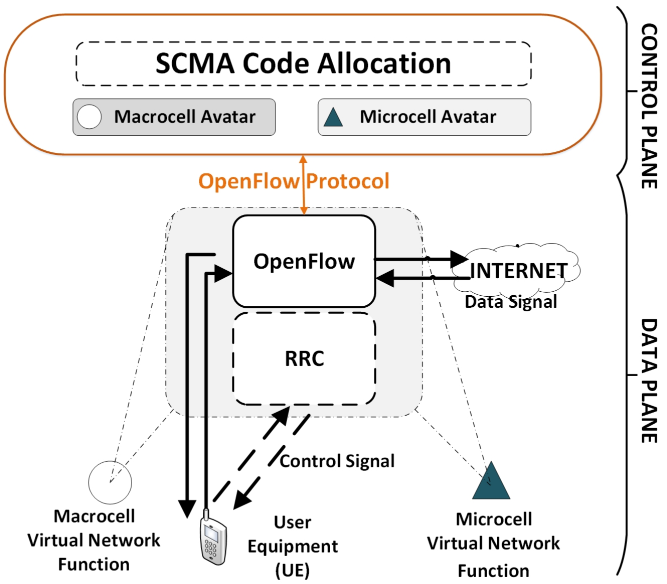

Figure 1: Proposed Network Architecture.

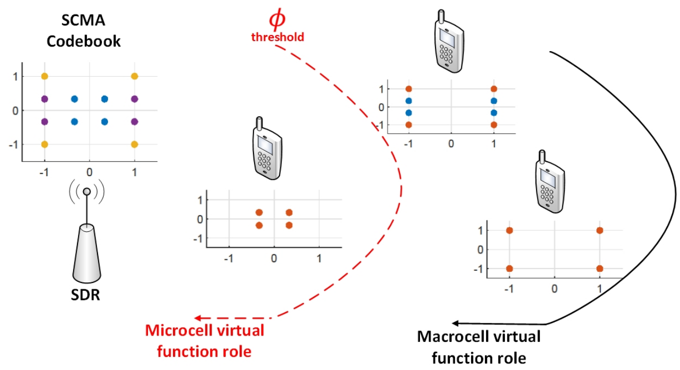

Figure 2: Macrocell and Microcell virtual network functions and an example SCMA Codebook in SDR.

configuration costs of network components. It is responsible for combining network functions in same platform where they quickly deployed. Therefore, we propose a novel SDN/NFV based secure SCMA design in SDR where the following contributions are mapped to these paradigms:

- SDN: User prioritization for SCMA codebook allocation according to analytically defined new QoS metric (ϕ), received power over overloading (P/λ)
- SDR: Secure SCMA codebook tranmission by asymmetric encryption algorithm,
- NFV: Software based implementation to meet low OPEX/CAPEX with either Macrocell or Microcell virtual network roles on the same SDR.

The rest of paper is organized as follows: In section II, the proposed network architecture is detailed in terms of both considering the wireless and wired communication links of SDR. In section III, the proposed system model is given by considering the protocol stack and the communication between control and data planes. Here, it is divided into three sub layers named as SDR, NFV, and SDN layers. In section IV, the performance evaluation of proposed SDR is given by relying on both theoretical and simulation results. As a result; in section V, the paper is summarized by giving the conclusion and the future work.

II. Proposed Network Architecture

The proposed network architecture of SDR is given in Fig.1. The network is decoupled by data and control planes. In data plane, there are SDRs which serves User Equipments (UEs) by 5G radio bearers. The data packets of UE are routed over the OpenFlow table through the Internet. This dummy part of physical component is controlled by considering OpenFlow messages taken from control plane where it communicates via OpenFlow protocol. This control messages are routed over wired communication link between SDR and controller. On the other hand; the attachment procedure is controlled by Radio Resource Control (RRC) layer in SDRs protocol stack. Here, SDR uses code based NOMA in order to increase the capacity of SDR, i.e. newly called SCMA. Previously, the OFDMA is used to serve UEs in LTE-A. It divides the resources only in the frequency domain, and nevertheless, this does not have been giving enough capacity for 5G devices. Therefore, we have capability to use of all constellation with SCMA codes to increase the SDR capacity. According to the decision of the controller in control plane, the high-powered SCMA codes would be assigned to UE which is far from SDR, whereas the low-powered SCMA codes would be assigned to UE which is near SDR. Here, the proximity of UE to SDR is also dynamically changed according to $\phi_{threshold}$, i.e. newly proposed QoS metric that is mathematically detailed in the following section. According to this threshold, SDR virtually serves UE by either Macrocell or Microcell roles. In control plane, there is an SDN/NFV controller which orchestrates physical components of data plane. Here; for each SDR, there are two avatars which are virtual representation of Macrocell and Microcell roles. They communicates with physical SDRs via OpenFlow protocol. They collects statistics from data plane, calculates ϕ value per UE periodically and dynamically generates SCMA codebook to increase the network capacity, and then, QoS of UE.

As shown in Fig.2, there is an example of generated SCMA codebook for an SDR. The mother codebook and assigned codebook for each UE's are given. According to the virtual role of SDR that would be shown to UE, a suitable code in SCMA codebook is assigned to UEs. Here, each codewords of a specific codebooks are differently colored in the figure. According to newly proposed $\phi_{threshold}$, SDR shows different roles to UE, which directly affects the SCMA codes of UE. For example; first UE has lower ϕ according to threshold, which means it has acceptable QoS; whereas, the other UEs have not acceptable ϕ. Therefore; SDR shows microcell role on first UE, macrocell role to others. From SCMA codebook; micro codes that would give worse QoS, and macro codes that would give better QoS are assigned according to this threshold level. SDR sends the related code to UE and it completes the attach procedure by using these assigned resources. Here, there can be malicious users which try to listen the communication of SDR and UE. Therefore, we also handle the security of SCMA codes by using asymmetric encryption as detailed in the following section.

III. System Model

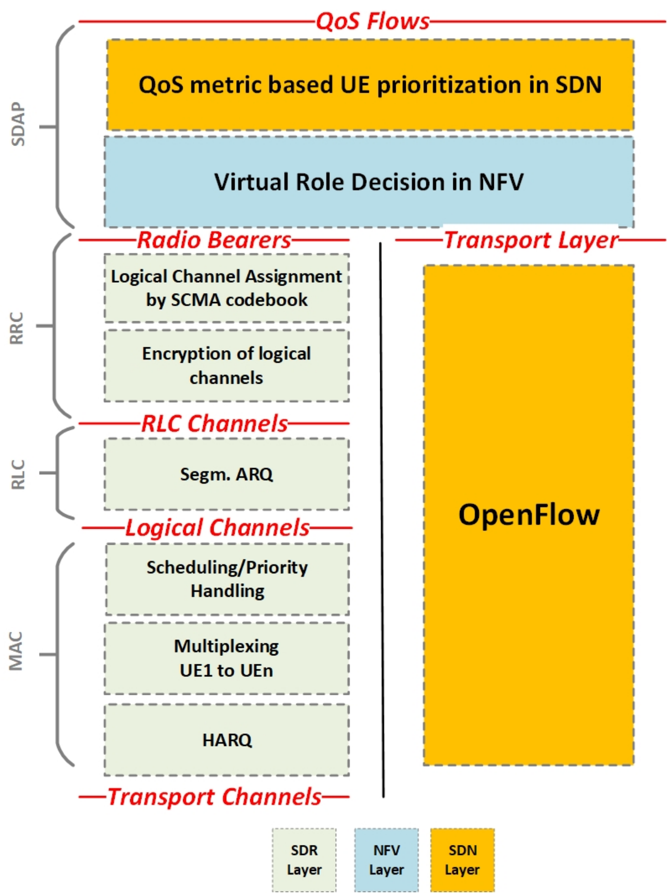

Figure 3: Proposed System Model and SDR Protocol Stack.

In Fig.3, the proposed system model is shown. This figure also combines SDN, NFV, and SDR concepts into one device. Each layer are differently colored. Here, SDR is responsible for the physical layer issues such as multiplexing users, signal processing, channel allocation, encryption/decryption of packets etc. SDN orchestrates the data plane dynamically by prioritization of UE. It dynamically differs UEs by using new QoS metric, ϕ and generates SCMA codes accordingly. It also focuses on the end to end transportation by embedding routing rules to OpenFlow table to guarantee QoS. On the other hand, NFV bring the different functional roles of SDR into same physical devices where the software implementation can be quickly deployed.

A. SDR layer

As shown in Fig.3; SDR has MAC, RLC and RRC layers in its' protocol stack. The MAC layer takes frames from allocated resources. It executes scheduling and prioritizing of UEs taken from physical channels. Then, the logical channels are sent to RLC layer for the error checking. Afterwards, RRC layer executes attach procedure by using radio bearers allocated according to SCMA codes as detailed in Fig.4. These SCMA codes are taken from upper layer, i.e. SDAP thanks to SDN/NFV layer.

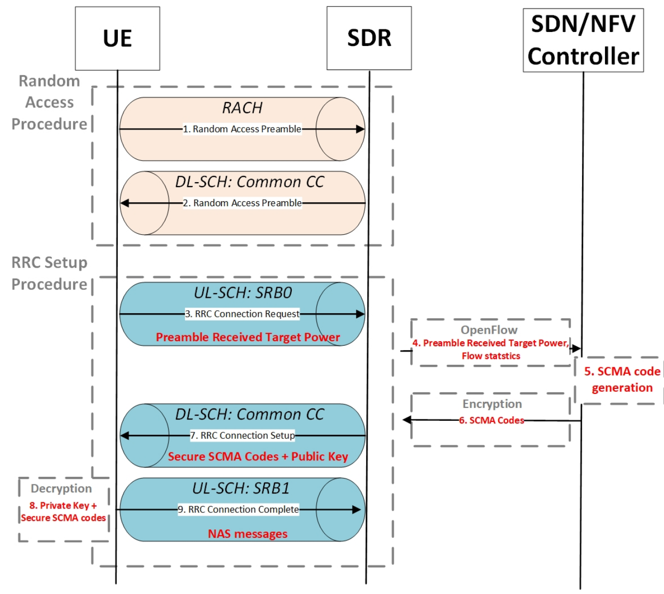

Figure 4: Communication Diagram of Proposed SDN/NFV based SDR architecture.

In Fig.4, the communication diagram of UE, SDR and SDN/NFV controller is shown. In 5G new radio, attach procedure is started with random access procedure (RACH). (1) UE transmits a specific preamble in a RACH slot. Here, there can be more than one UE who send data in same slot. Therefore, it listens DL-SCH to see its' preamble is accepted by SDR. (2) In this message, SDR sends also temporary identity C-RNTI used between UE and SDR communication. Afterwards, Radio Resource Control (RRC) setup procedure is initated. (3) By using C-RNTI, UE sends RRC connection request to SDR. Here, SDR should resolve the contention between multiple UEs near by the increasing the resource capacity. Therefore, it start to generate SCMA codebook dynamically. (4) To handle this process, it takes preamble received target power from UE which would show the proximity of UE to SDR. Moreover, it takes flow statistics from OpenFlow tables to calculate the overloading of SDR. (5) By using these parameters it generates SCMA codes and (6) returns it to SDR. In order to handle the security of codes assigned to UE, SDR encrypts the message by using own private key and UE's public key. (7) UE taking this downlink message verifies the message by SDR's public key and decrypts the code by using own private key. (8) Now, UE completes the RRC by using SCMA codes allocated itself.

Then, it continues to NAS procedure to tunnelling of Core network [16].

B. SDN layer: QoS metric based UE prioritization

In this paper, we've analytically modeled a QoS Parameter $\phi_{ij}(t)$, with respect to preamble target received power ($P_{ij}(t)$) and the overloading of SDR ($\lambda_j(t)$) for each user i and each SDR base station j. This parameter with unit of ($dB \cdot sec/flows$), is represented as below:

$$\phi_{ij}(t) = \frac{P_{ij}(t)}{\lambda_j(t)} \qquad \forall i \in N, j \in M \tag{1}$$

where $\lambda_j(t)$ is calculated by its own avatar with the help of a flow statistical service in a centralized SDN controller. Here, it takes statistics periodically (per 1 sec) and calculates the difference in the number of matched OpenFlow flows in SDR in a period of time ($J = \sum \lambda_i$). By using it, the overloading (λ_j) is calculated as follows:

$$\lambda_j = \frac{\sum_i \lambda_i}{K_j} \qquad \forall i \in N, j \in M \tag{2}$$

where K_j is the number of Resource Equipments (RE) in SDR. We consider the overloaded cases where $\lambda > 1$. For example, there are 9 UEs[1] and 6 REs in SDR; i.e. overloading is calculated as $\lambda_j = 150\%$. In that case conventional resource allocations such as OFDMA, are not enough to keep QoS of UE in acceptable level. The numerator and denominator of λ also represents the number of columns and rows in SCMA codebook matrix as exemplified below, respectively:

$$F[K,J] = \begin{bmatrix} 1 & 0 & 0 & 0 & 1 & 1 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 & 0 \\ 0 & 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \end{bmatrix}. \tag{3}$$

On the other hand, $P_{ij}(t))$ is calculated in unit of db by using the following general formula [17]:

$$P_{ij}(t) = P_{tj}(t) + G_{tj}(t) + G_{ri}(t) - PL_{ij}(t) \qquad \forall i \in N, j \in M \tag{4}$$

where all of the terms in unit of dB. Here; $P_{tj}(t), G_{tj}(t), P_{ri}(t)$ indicates transmit power, gain of transmit antenna, and gain of received antenna of SDR, respectively. $PL_{ij}(t)$ is path loss between j^{th} SDR and i^{th} UE. $P_{tj}(t), G_{tj}(t)$ are constant for each base station in heterogeneous networks, and $G_{ri}(t)$ is also constant for each user device.

According to 3GPP technical report for 5G new radio, $PL_{ij}(t)$ is differently defined [16] in terms of Urban Microcell, Urban Macrocell as shown in (7). Here, pathloss is defined according to Line of Side (LOS) scenario for Macro and Micro environments of SDRs. For Macro and Micro; the distance between i^{th} UE and j^{th} SDR ($D_{ij}(t)$) provides $d'_{BP} \leq D_{ij}(t) \leq 5km$, $h_{BS} = 25m$, and $1.5m \leq h_{UT} \leq$ $22.5m$. In (7), $D_{ij}(t)$ is calculated according to 3D space by using following formula:

[1]Here, we've assumed that there is one flow per UE

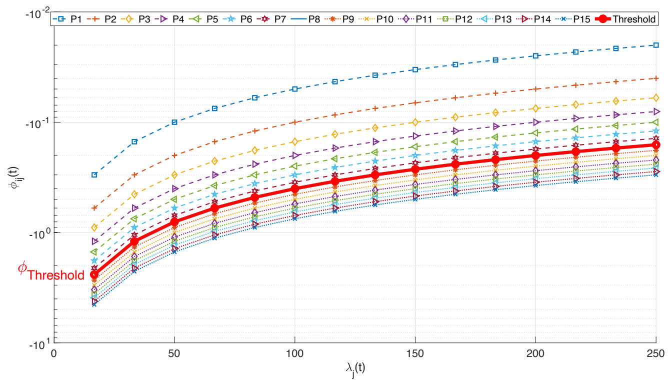

Figure 5: ϕ vs overloading (λ) analysis for different power levels.

$$D_{ij}(t) = \sqrt{{d_{2D}}^2 + (h_{BS} - h_{UT})^2} \tag{5}$$

Moreover, d'_{BP} is calculated as follows:

$$d'_{BP} = \frac{4h'_{BS}h'_{UT}f_c}{c} \tag{6}$$

where $c = 3 \cdot 10^8 m/s$ and f_c is center frequency of SDR and it provides $0.5 \leq f_c \leq 100GHz$. h'_{BS}, h'_{UT} are effective antenna heights at the SDR and UE where the distribution function is assumed constant. Therefore, they are calculated as $h_{BS} - 1$ and $h_{UT} - 1$, respectively. By using eqs.1,7 and inline definitions; the whole formula of QoS metric is given in (8). Because of using db unit in power; QoS metric, ϕ is defined in negative values.

In Fig.5, the analysis of proposed QoS metric (ϕ) is given. In y-axis, there is the calculated ϕ according to (8), whereas in x-axis there is the overloading of SDR according to (2). Due to defining in unit ($db{\cdot}sec/flows$), the calculated ϕ is in negative values. Therefore; as the ϕ increases, the QoS metric becomes worse. According to figure; as overloading (λ) increases up to 250%, the ϕ gradually becomes worse compared to less dense SDR. While considering different power levels, the $\phi_{threshold}$ has been determined as dynamically changeable according to different overloading (λ) parameter of SDR. This threshold is shown as red line in the figure.

Thanks to the proposed QoS metric (ϕ), UE can be prioritized to assign better SCMA code to UEs who have non acceptable QoS according to $\phi_{threshold}$. Therefore, we firstly run UE prioritization algorithm where the pseudo code is given in Alg.1. It experimentally takes flow statistics from OpenFlow table of SDR and preamble Received Target Power in RRC layer of SDR, and theoretically calculates ϕ given in (8). It returns avatar lists which includes UEs seeing SDR in either Macrocell role or Microcell role. This algorithm runs for all SDR in the topology in parallel to reduce complexity of the algorithm, and then, this decreases the response time of SDN/NFV controller. It initialize avatar lists in line 2. It runs a

Algorithm 1 UE Prioritization Algorithm

Require: Flow Statistics, preamble Received Target Power
Ensure: UE-Avatar assignment
1: **for all** SDR_j in topology **do** in parallel
2: Initialize Avatar lists $A_{Micro} \leftarrow \{\}$, $A_{Macro} \leftarrow \{\}$
3: **for all** UE_i in SDR_j **do**
4: $\lambda_i \leftarrow$ flow statistics of UE_i from OpenFlow table
5: $P_{ij} \leftarrow$ preamble Received Target Power of UE_i in RRC connection setup
6: Calculate $\lambda_j \leftarrow (\sum \lambda_i)/K_j$
7: Calculate ϕ_{ij} ▷ (8)
8: **if** $|\phi_{ij}| < |\phi_{threshold}|$ **then**
9: Assign UE_i to A_{Macro} ▷ Macro UE
10: **else**
11: Assign UE_i to A_{Micro} ▷ Micro UE

loop defined between lines 3-12 for each UE in SDR. In line 4, it takes flow statistics and in line 5 it takes preamble received target power of UE. Then, it calculates the overloading of SDR in line 6. It performs, (1) in line 7 to calculate newly defined QoS metric, ϕ. According to $\phi_{threshold}$, the UE is assigned to either Macrocell or Microcell avatar lists of SDR between lines 8-11. Therefore, they are newly called as Macro UE or Micro UE. Here, each role has different SCMA codebooks which were previously generated only once as detailed in following subsection.

C. NFV layer: Virtual role decision and Code Assignment

According to QoS metrics, the virtual role of SDR which would be shown to UE should be decided to assign SCMA codes which are previously generated for Macrocell and Microcell roles accordingly. An SDR can have Macrocell and Microcell virtual roles which has software deployment to physical component easily. Alg.2 requires Avatar lists from Alg.1, and returns encrypted logical resources R^e (SCMA code) per UE. This algorithm runs per Avatar in parallel. It considers all SDRs in the topology and each UE. In line 2, it generates SCMA codebook per SDR. Lines between 3 and 9 performs for each UE in SDR. In line 4, a temporary $Role$ is initialized which would show SDR virtual role seen by UE. Between lines 5-8, this role is set either Macrocell or Microcell virtual function according to avatar lists, A_{Macro} and A_{Micro} decided in Alg.1. In line 9, the CodeAssignment function, defined between lines 10-24, is called according to $Role$ decision of SDR seen by UE. In this function, a temporary avatar list is initialized and according to $Role$, avatar lists are copied to this temporary array between lines 12-15. Then, for each UE in avatar list (either macro or micro avatar list), according to $Role$ of SDR seen by UE, codes from SCMA codebook are allocated to UE. If $Role$ is Macrocell virtual function, the high codes are assigned to UE; in the opposite case, the low codes are assigned to UE between lines 17-21. Finally, assigned logical resources (codes) are encrypted by using UE's public key and SDR's private key in line 22 and returned as in line 23. This message would decrypted by UE's private key and SDR's public key in receiver side.

Algorithm 2 Virtual Role Decision Algorithm

Require: Avatar lists
Ensure: Encrypted Logical Resources RE^e from SCMA codebook $F[K, J]$
1: **for all** SDR_j in topology **do**
2: Initialize generated SCMA codebook, $F[K, J]$
3: **for all** UE_i in SDR_j **do**
4: Initialize $Role$ of SDR shown to UE
5: **if** $UE_i \in A_{Macro}$ **then**
6: $Role \leftarrow$ Macrocell vFunction Role
7: **else**
8: $Role \leftarrow$ Microcell vFunction Role
9: $R^e \leftarrow$ CODEASSIGNMENT(SDR_j, $Role$)
10: **function** CODEASSIGNMENT(SDR_j, $Role$)
11: Initalize TempArray $A \leftarrow \{\}$
12: **if** $Role$ is Macrocell **then**
13: Copy Macro list to temporary array, $A \leftarrow A_{Macro}$
14: **else**
15: Copy Micro list to temporary array, $A \leftarrow A_{Micro}$
16: **for all** $UE_i \in A$ **do**
17: Initialize $RE \leftarrow []$
18: **if** $Role$ is Macrocell **then**
19: $RE \leftarrow$ **Macro** codes from $F[K, i]$ ▷ (3).
20: **else**
21: $RE \leftarrow$ **Micro** codes from $F[K, i]$ ▷ (3).
22: $RE^e \leftarrow$ Hash RE with shared public key
23: **return** RE^e
24:

IV. Performance Evaluation

In the performance evaluation, the proposed SDR is emulated on ONOS-2.4.0 controller as Control plane by using Mininet environment as Data plane. Two example SDRs which are also OpenFlow switches are executed with two different UE pairs. They've performed UDP based video streams through the simulation time. During this scenario, ONOS controller takes statistics periodically. To do that, it sends a control message named as ofp_flow_request to OpenFlow switches and it takes statistics by an another control message named as ofp_flow_stats. The example results of the taken statistics on the centralized controller is given in Fig.6. It shows overloading (λ_j) as defined in (2) in y-axis, and simulation time in x-axis. As an exemplified, one of SDR can reach up to 150% overloading according to taken flow statistics. Therefore, in this paper we focus on this parameter where the details are also defined in Table I.

Afterwards, the simulation is performed over MATLAB ©2019b. During the simulation, there is one SDR which can have two virtual roles such as Macrocell and Microcell. The antenna parameters are given in the table. On the other hand, in

$$PL_{ij}(t) = \begin{cases} 28.0 + 40log_{10}(D_{ij}(t)) + 20log_{10}(f_c) - 9log((d'_{BP})^2 + (h_{BS} - h_{UT})^2), & Macro \\ 32.4 + 40log_{10}(D_{ij}(t)) + 20log_{10}(f_c) - 9.5log((d'_{BP})^2 + (h_{BS} - h_{UT})^2), & Micro \end{cases} \quad (7)$$

$$\phi_{ij}(t) = \overbrace{\frac{K_j}{\sum \lambda_i}}^{\lambda_j^{-1}} \cdot \overbrace{\begin{cases} P_{tj}(t) + G_{tj}(t) + G_{ri}(t) - 28.0 + 40log_{10}(D_{ij}(t)) + 20log_{10}(f_c) - 9log((\frac{4(h_{BS}-1)(h_{UT}-1)f_c}{c})^2 + (h_{BS} - h_{UT})^2), & Macro \\ P_{tj}(t) + G_{tj}(t) + G_{ri}(t) - 32.4 + 40log_{10}(D_{ij}(t)) + 20log_{10}(f_c) - 9.5log((\frac{4(h_{BS}-1)(h_{UT}-1)f_c}{c})^2 + (h_{BS} - h_{UT})^2), & Micro \end{cases}}^{P_{ij}} \quad (8)$$

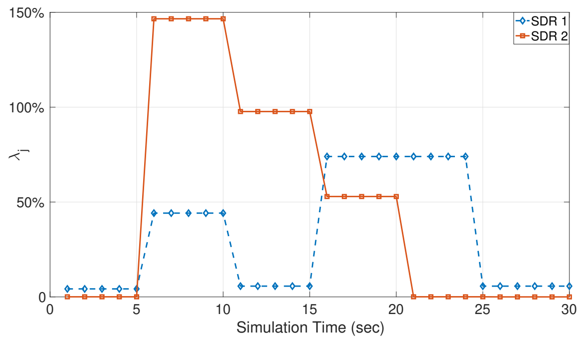

Figure 6: An Example of Taken Statistics on SDR Controller.

SCMA codebook assignment of SDR the Low-density parity-check code (LDPC) is used for channel coding where the rate is 1/2. By using these parameters, there are graphs that show RE assignments as the output of Algs.1 and 2. The effect of these assignments are also shown in performance analysis with Bit Error Rate (BER) value.

SDR parameters	
P_{Tj}	Macro 36 dBm, Micro 27 dBm,
G_{Tj}	Macro 15 dBi, Micro 8.5 dBi
G_{ri}	2 dBi
h_{BS}	15 m
h_{UT}	1 m
f_c	FR1 (7 GHz)
d_{2D}	Macro [0,35m] , Micro [0,10m]
SCMA Codebook Parameters	
Number of RE (K)	6
Number of UE (J)	9
Overload (λ_j)	150%
Number of RE for each UE	2
Number of UE for each RE	3
Total Data	1040400
Channel Coding	Low Density Parity Check(LDPC)
Coding Rate	1/2

Table I: Simulation Parameters[18][4].

In Fig.7, the usage of a resource equipment (RE) from different UEs are shown for a same period of time. These assignments can change when time flows. In this simulation, there are K=6 REs and $\sum \lambda_i$=9 UEs; and therefore, the overloading λ_j is calculated as 150%. As a result of simulation, the first RE is used by UE_1, UE_5, and UE_6 at the same time with different codebook assignments. The details of these assignments are also differentiated in Fig.8. Here, each UE's resources are shown in the graphs. By considering Figs.7 and 8, the first RE in Fig.7 shows the total codes of first, fifth and sixth codes in Fig.8. Other assignments can be interpreted in

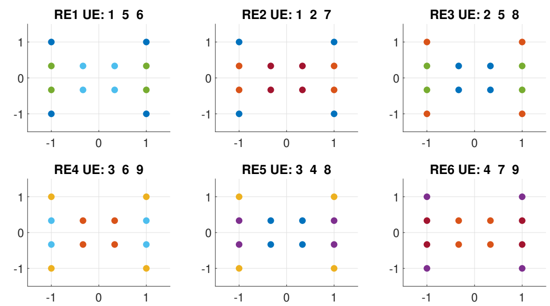

Figure 7: REs used by different mobile UEs when $\lambda_j = 150\%$.

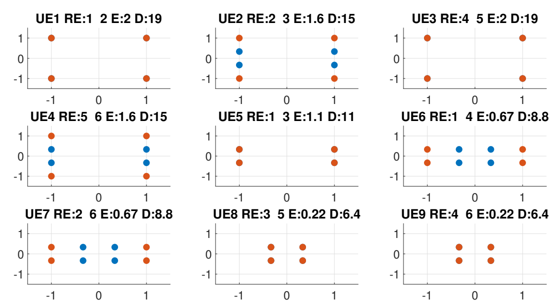

Figure 8: Mobile UEs and their assigned REs when $\lambda_j = 150\%$.

the same way. These assignments are performed in Algs.1 and 2.

According to these code assignments in proposed algorithms, the performance analysis of all UEs are shown in Fig.10. In this graph, Bit Error Rate (BER) is given in y-axis and the ratio of the energy rate per bit (Eb) and spectral noise density (No) is given in x-axis. Here, some UEs are in Macro array of SDR, where it shows Macrocell virtual role to them. Namely, the QoS metric ϕ of these UEs are acceptable according to the varying threshold in time. Therefore, the Macro codes from generated codebook are assigned in Alg.2. These codes outputs worser performance to these UE in terms of BER value. To consider whole topology; the BER results of Macro and Micro UEs are given in Fig.10. According to Macro and Micro code assignments, Micro UEs have 10x higher BER value than Macro UEs. Here, the Macro UEs are also in acceptable BER results by considering average in a topology.

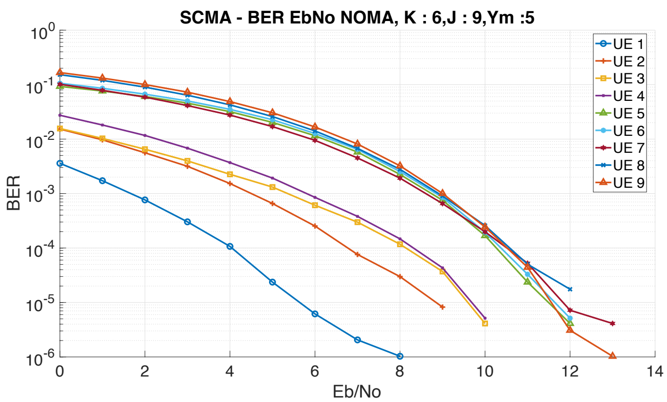

Figure 9: BER analysis of all UE in a topology

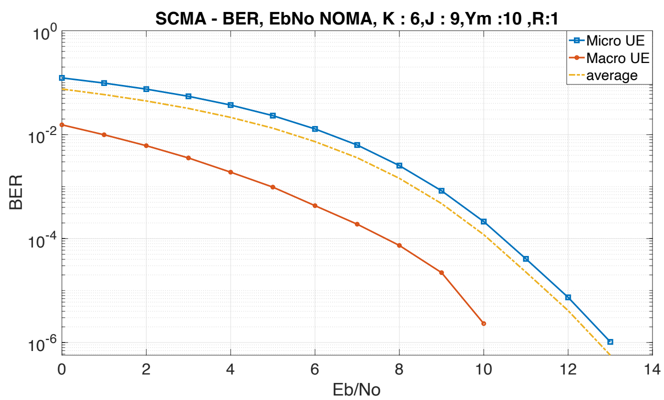

Figure 10: Average BER analysis according to UE prioritization as Macro and Micro UE

V. Conclusion and Future Work

In this paper, we proposes a novel SDN/NFV based secure SCMA design in SDR. With SDN; UE prioritization such as Macro UE and Micro UE, is performed in SCMA codebook allocation according to analytically defined new QoS metric (ϕ). With NFV, an SDR can have two different role to UE by Macrocell and Microcell virtual networks functions. With SDR, SCMA codebook transmission is performed by asymmetric encryption algorithm to protect UE privacy. According to the results, as the overloading (λ) is increased up to 250%, the proposed QoS metric (ϕ) gradually becomes worse compared to less dense SDR. With dynamically changeable $\phi_{threshold}$ in SDN controller; Micro UEs has 10x higher BER than Macro ones where the average BER is in acceptable range in the whole topology. As a future work, the proposed ϕ parameter will be extended by considering also dynamic code-book generations for the different traffic types of mobile UE. Moreover, by using an AI-based algorithm the codebook generation will be optimized by considering the cost of the proposed algorithms and the scalability of the controller.

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