# Improvement of System Capacity using Different Frequency Reuse and HARQ and AMC in IEEE 802.16 OFDMA Networks

Dariush Mohammad Soleymani, Vahid Tabataba Vakili

***Abstract*— IEEE 802.16 OFDMA network (WiMAX) is promising technology which defines PHY and MAC layer for fixed and mobile profile. The WiMAX systems need effective QOS to provide broadband wireless access. The interference is one of major problems in wireless networks, frequency reuse and Adaptive Modulation Scheme (AMC) and Hybrid Automatic Repeat request (HARQ) are different network deployment causes to retain network QOS. This paper is based on simulation of Signal to Interference plus Noise Ratio (SINR) in 802.16 systems, the QOS metric of throughput and outage probability are estimated, according to assessment criterions, the system Performance on combination of different frequency reuse and AMC and HARQ are evaluated. In our novel method, we found that combination of Fractional Frequency Reuse (FFR) and Aggressive AMC parameters with HARQ algorithm will give us the optimal network configuration which can be applied as reference parameters in the practical networks.**

***Index Terms— IEEE802.16 OFDMA, AMC, HARQ, Frequency Reuse***

## I. Introduction

The IEEE802.16 OFDMA technology (WiMAX) is based on the IEEE 802.16-2004,2005,2009 specifications[5],[7],[9]which define a physical layer and Medium Access Control(MAC) layers for mobile and fixed broadband wireless access systems operating at frequency below 6 GHz. The WiMAX has selected OFDMA modulation to improve multipath fading in the Downlink and Uplink. It is also applied Time Division Duplexing (TDD) or Frequency Division Duplexing (FDD).

The Mobile Station (MS) should have adequate signal quality to take service from network; the WiMAX networks support a number of methods to achieve better throughput and less interference. In respect to OFDMA modulation sub-channel permutation are important for averaging interference in an interference–rich environment. There are two different type of permutation Full Usage Sub-channel (FUSC) and Partial Usage Sub-channel (PUSC).
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For simplicity, we just apply PUSC in Downlink (DL) and uplink (UP).These permutations mitigate cross-interference between neighboring cells by minimizing the number of hit that any number of sub-channels of one cell measures from a single sub-channel of neighbor cell [11].

Another solution to mitigate interference is frequency reuse, it refers to distribution of available bandwidth across the cells and sectors, the typical nomination is [number of cell sites*number of sector per site *number of frequency bunch required]. The standard frequency reuse which applied in WiMAX is [1×3×1] and [1×3×3]. In the [1×3×1] algorithm all sectors apply same frequency band leading to have interference from all neighboring sectors within networks, but in the [1×3×3] systems different frequency group is used in the sectors resulting users have less interference from others users [4].

Recently, Fractional Frequency Reuse (FFR) is gaining more attention to reduce interference of cell edge users. The FFR is dividing cell to inner and outer areas, it allocates [1×3×1] system to inner area and [1×3×3] system to outer area, resulting to have less interference and more throughputs for cell edge users [4].The HARQ and AMC are two error protection mechanisms that we are presenting their effects on throughput and SINR in this paper. For the connection that requires enhanced reliability, WiMAX support HARQ. In this mechanism each transmitted packet is acknowledged by receiver. The HARQ is using rehearsal algorithm to get correct block if it received block with error or delay, the MAC layer is informed to transmit the corrupted block, this situation cause to have less block error rate(BLER) [1],[7].

The WiMAX supports a number of modulations and Forwards Error Correction (FEC) coding schemes and allows schemes to be changed over one per user and per frame basis, based on channel quality. The AMC is a mechanism to optimize channel throughput. The Adaption Modulation and Coding (AMC) based on signal to noise and interference ratio measured in the receiver and provide highest possible data rate for each user [9].

The purpose of this study was to obtain new configuration to improve throughput and outage along with Signal to Noise Ratio (SNR). In the [4] it is just studied on the location of edge user and ratio of inner area to outer area in the performance criterions; in the [2] they took the effect of scenario. Finally, in the second scenario we investigated effect of combination of the aggressive AMC table in conjunction to HARQ and different frequency reuse schemes. Our study was different from the previous work, as we apply the FTP explicit traffic with big size file downloading and we measured all this creations for moving

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ISBN: 978-988-19251-9-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

subscriber, so it will be beneficial for real network assessment.

### A. Adaptive Modulation Coding

The idea behind AMC is choosing the modulation and channel scheme according to channel conditions, to achieve highest spectral efficiency. Depend on the channel quality service the mobile station transmits in high or low data rate in order to avoid excessive dropped packets. Lower data rates are achieved by using small constellation, such as QPSK and low rate error-correction code such as ½ convolution codes. High data rate are using 64 QAM modulation and less robust error correction codes such as ¾ convolution codes. In the "Fig.1" we are presenting AMC block diagram. As shown in "Fig.1" the transmitter for choosing suitable coding and modulation needs to know the channel SINR which defined as the received SINR in the receiver divided by transmit power. According to these measurements, modulation and coding is elected [2], so transmit power, transmit rate, and the coding rate in the AMC were controlled. The feedback will be received with delay and error in channel estimation. Therefore, the WiMAX system protects the feedback with error corrections algorithms. Empirically, using suitable AMC mobile station parameters show that we will achieve more throughput and efficiency in the network.

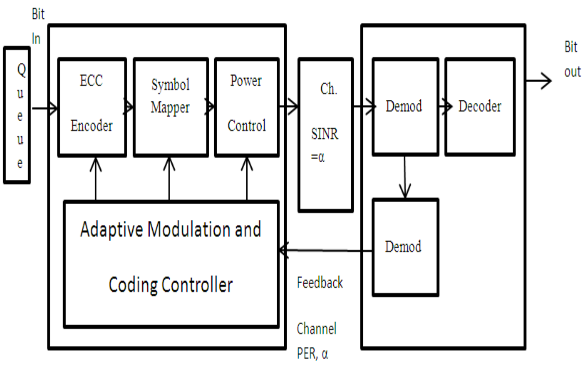



Fig.1. AMC BLOCK DIAGRAM

### B. Frequency Reuse (1×3×1)

One of key benefits of OFDMA air interface is its capability in frequency reuse 1. This will allow using same frequency channel throughout the cellular network, and it causes to have fewer problems in frequency planning. The data rate in the (1×3×1) scheme is definitely low.

This happens because in this case, the cell edge user experiences lower SINR, due to co-channel interference and thus achieves lower throughput.

It should be noted that although we obtain more spectral efficiency in the case, but we will lose more performance for cell edge user. Empirically, we apply identical permutation base in frequency reuse as we investigated in this frequency scheme it will not provide better SINR in the network [4].

### C. Frequency Reuse (1×3×3)

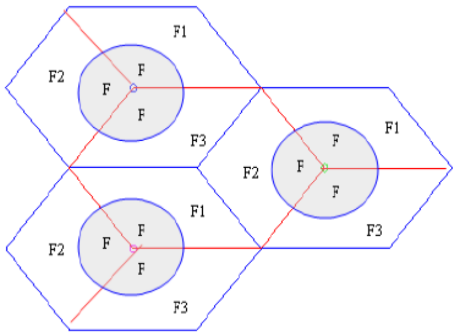
In order to achieve an acceptable cell edge performance it is required to use segmentation, all the sub-channel divided to three segments and three sectors is allocated one group of sub-channels. Although the average channel throughput is less in the case of (1×3×1) frequency reuse than for (1×3×3) reuse, the overall capacity is higher with (1×3×1) reuse, since each sector is allocated three channels as opposed to one channel in the case of (1×3×3) reuse. On the other hand, network reliability is significantly improved by going from (1×3×1) reuse to (1×3×3) reuse. In this algorithm we just consider to same permutation base (PERMBASE).Our analysis showed using different PERMBASE causes to have less SINR than we apply identical PERMBASE within network [4].

### D. Fractional Frequency Reuse

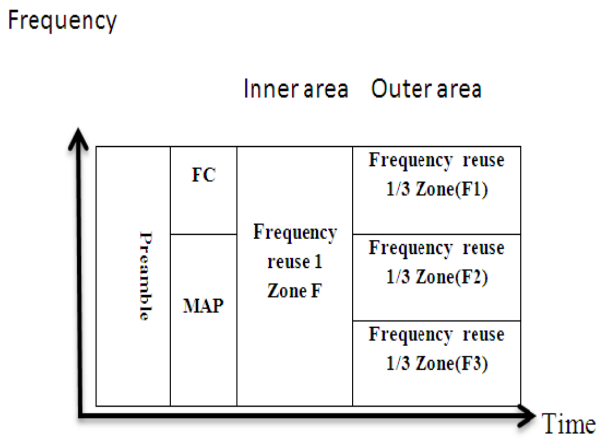
In FFR, each cell divided into two areas, inner and outer, each area using different frequency reuse factor. Generally, inner area that we expected good signal quality in it, used (1×3×1) and in outer area, which we expected less quality it is applied (1×3×3) reuse [1]. The different study has recently been made to investigate the inner to outer ratio [4]. In every frame, each user will calculate SINR and send it to base station. In the base station based on inner and outer boundary, which take the propagation model during calculation into consideration make decision that this user belong to inner or outer area then we devote determined amount of sub-channel and subcarrier to a user.

The "Fig.2" Show fractional frequency reuse principal "Fig.2a" and DL-sub frame structure "Fig.2b" [3], [7].

This paper is organized as following. In section II we explain our system models and scenarios. Section III describes performance metrics and performance evaluation criterion. The results and discussions are mentioned in the section IV. Finally, section V concludes the paper.




(a) FFR structure




(b) DL-sub frame structure

Fig. 2 Fractional Frequency Reuse and DL-sub frame structure for the base stations.

## II. SYSTEM MODELS AND SCENARIOS

As shown in “Fig. 3”, We study an IEEE 802.16 OFDMA network consist of 19 cells and 57 sectors, we use OPNET 14.5 modeler [8] which is an extensive networking tool in analyzing the performance of the network. We apply tri-sector base station model, we also use 120-degree antenna pattern in our simulator, the base station and subscriber station simulation parameters has been listed in “Table I”. Two scenarios were constituted in the scenario I; we just apply conservative AMC parameters as shown “Table II” [2], without using HARQ in different frequency reuse schemes. In the scenario II, the aggressive AMC as shown “Table III” [2] with HARQ algorithm, while using different frequency reuse schemes, were evaluated. We used standard FTP traffic model in the both scenarios [1]. We are investigating different frequency reuse factors with above scenarios and observing the result, this model has experimental benefit for the WiMAX operators.

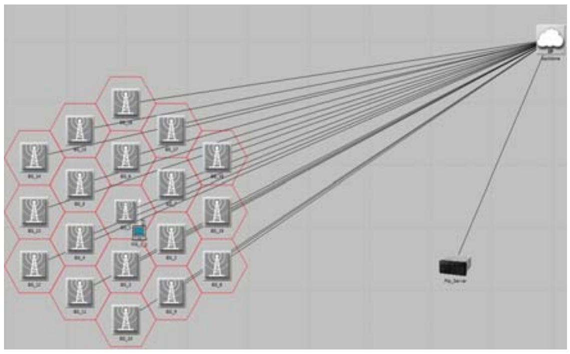


Fig.3 the WiMAX model in OPNET 14.5.

TABLE I.
BS AND MS PARAMETERS

| Parameter Name | Value |
|---|---|
| *Carrier frequency* | 3.5GHz |
| *Channel bandwidth* | 10 MHz |
| *FFT size* | 1024 |
| *Duplexing technique* | TDD |
| *Pathless* | Free space |
| *BS output power* | 20W |
| *MS output power* | 0.5 W |
| *BS antenna* | 15 dB,120 degree |
| *MS antenna* | -1dB,360 degree |
| *Cell radius* | 1Km |
| BS Ant. height | 40m |
| MS height | 1.5m |
| Terrain type | Type A |
| Service flow | UGS,64k |

TABLE II.
CONSERVATIVE AMC VALUES

| Row | Mandatory Exit(dB) | Minimum Entry(dB) | Modulation and Coding |
|---|---|---|---|
| 0 | -20.0 | 2.0 | QPSK1/2 |
| 1 | 11.0 | 11.9 | QPSK3/4 |
| 2 | 14.0 | 14.9 | 16-QAM ½ |
| 3 | 17.0 | 17.9 | 16-QAM ¾ |
| 4 | 20 | 20.9 | 64-QAM ½ |
| 5 | 23 | 23.9 | 64-QAM 2/3 |
| 6 | 25 | 25.9 | 64-QAM ¾ |

TABLE III. AGGRESSIVE AMC VALUES

| Row | Mandatory Exit(dB) | Minimum Entry(dB) | Modulation and Coding |
|---|---|---|---|
| 0 | -20.0 | 2.0 | QPSK1/2 |
| 1 | 5.0 | 5.9 | QPSK3/4 |
| 2 | 8.0 | 8.9 | 16-QAM ½ |
| 3 | 11.0 | 11.9 | 16-QAM ¾ |
| 4 | 14.0 | 14.9 | 64-QAM ½ |
| 5 | 17.0 | 17.9 | 64-QAM 2/3 |
| 6 | 19.0 | 19.9 | 64-QAM ¾ |

## III. PERFORMANCE METRICS AND EVALUATION CRITERION

In this paper, the system capacity and coverage performance are examined. We defined system capacity as total achieved throughput in the system. At each snapshot, we calculate the Signal to Noise plus Interference Ratio (SINR) at receiver side over all sub-channels and sub-carriers for a user.

For each BS and SS link, the simulator computes the channel and interference power on loaded data sub-carriers. The received signal power level at $k_{th}$ sub-carrier for $m_{th}$user is calculated as (1):

$$P_{RX}^{m} = P_{TX}^{m}.P_{loss}^{m}.\frac{|h_m(k)|^2}{N_{load}(j)} \quad (1)$$

Where, $P_{RX}^{m}$is transmitted power from BS or $m_{th}$SS,$P_{loss}^{m}$ is path loss including shadowing and antenna gain and $N_{load}(j)$ is total number of co-channel sub-carriers for$j_{th}$ OFDMA symbol,$h_m(k)$ is also pulse function between $l_{th}$interferer and $m_{th}$target user.The co-channel power level calculated as in (2):

$$P_{CCI}^{m}(k) = \sum_{l=2}^{N_{CCI}} P_{CCI}^{m,l}(k) = \sum_{l=2}^{N_{CCI}} P_{TX}^{l}.P_{loss}^{m,l}.\frac{|h_{m,l}(k)|^2}{N_{load}(j)} \quad (2)$$

Where,$P_{CCI}^{m,l}(k)$ is co-channel power level from the $l_{th}$interferer to $m_{th}$ user and$N_{CCI}$ is number of co-channel interferes. Finally, we calculate SINR as in (3):

$$SINR^{m}(k) = \frac{P_{RX}^{m}(k)}{\sigma_n^2 + P_{CCI}^{m}(k)} = \frac{P_{RX}^{m}(k)}{\sigma_n^2 + \sum_{l=2}^{N_{CCI}} P_{CCI}^{m,l}(k)} \quad (3)$$

Where, $\sigma_n^2$ is average white gauss noise power level (AWGN).

The second criterion in performance is throughput which we are using as in (4).

$$throughput = (1 - BLER)r\log_2(M)\frac{bps}{HZ} \quad (4)$$

Where, BLER is block error rate, r≤1 is the coding rate, and M is number of point in the constellation [3].Many of papers used outage as individual performance criterion in their papers [4], but we took it in throughput CDF function into consideration and comparing probability value when the throughput got zero.

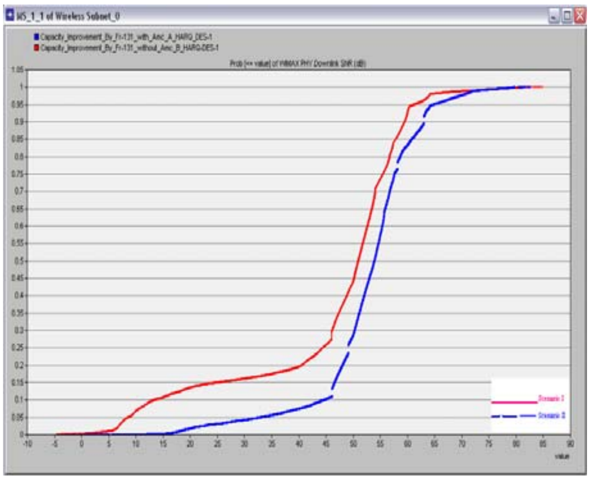
## IV. RESULT AND DISCUSSION

The performance analysis and validity of different frequency reuse schemes provided in the standard have been done by several parameters including throughput and Signal to Interference plus Noise Ratio (SINR) for File Transfer Protocol application (FTP).

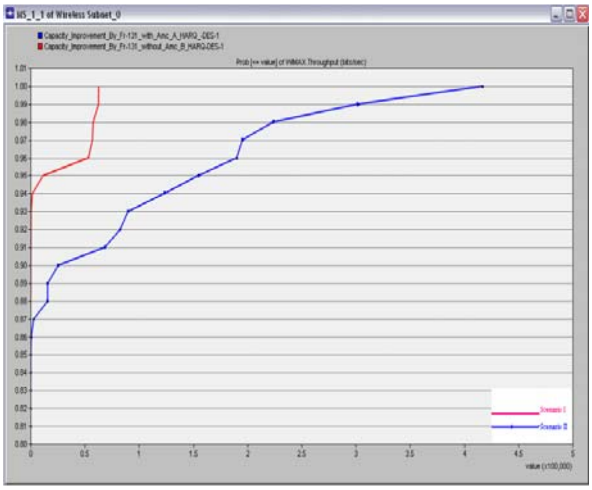
In the “Fig.4”, we are investigating in SINR and throughput for (1×3×1) schemes, when we applied Scenario I and II, apparently, we used CDF graph to show difference between two scenarios. As shown in “Fig.4”for edge cell user we have 10 dB improvements and in inner area we are achieving 2.5dB better coverage. In the comparison to scenario I, in the “Fig.4a”, we are getting 550Kbps throughput by using scenario II which we cannot get more than 65Kbps by using scenario I.

In the “Fig.5a”, the SINR for (1×3×3) illustrated that using Scenario II shows 15dB improvement in SINR comparing to scenario I. In the “Fig.5b”, we are comparing the throughput for both scenarios as shown in this figure, maximum throughput will be around 200Kbps and the outage [4] in the Scenario II will be less than the scenario I. It can also be derived from CDF function the better throughput probability in the scenario II comparing to the scenario I. In the “Fig.6” the SINR and throughput for the fractional frequency reuse scheme was illustrated. As shown in the “Fig.6” We have 2.5dB improvement by using the scenario II comparing to the scenario I. We also can see if we apply scenario II in the FFR**,** we will get 1Mbps average throughput but in scenario I this value will be around 150Kbps. In the “Fig.6a”, we are getting 2.5 dB improvements in the SINR by using Scenario II. Comparison of throughput and outage in all methods shows, we can obtain better throughput and less outage by applying fractional frequency reuse in the scenario II. As shown in the figures, the outage probability in the (1×3×1) and (1×3×3) schemes are 0.85 and 0.65 values in sequence, but by using the FFR with scenario II , we are achieving to the value of 0.48 in, so we conclude using our novel model will give less outage than the other methods. Finally, we will achieve 1Mbps throughput by applying our model that this value greater than other method which we discussed in this paper.

ISBN: 978-988-19251-9-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)

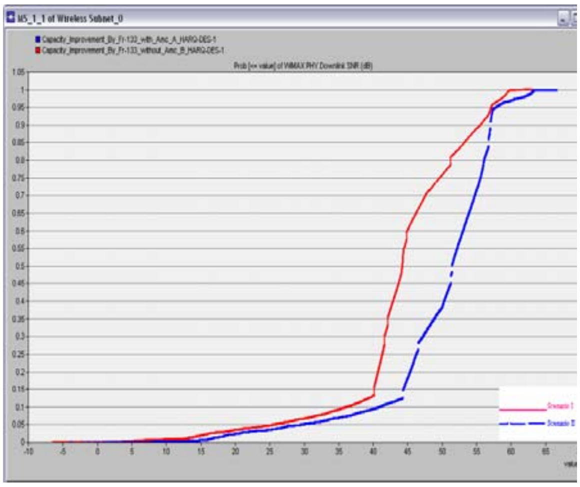


(a) Average SINR

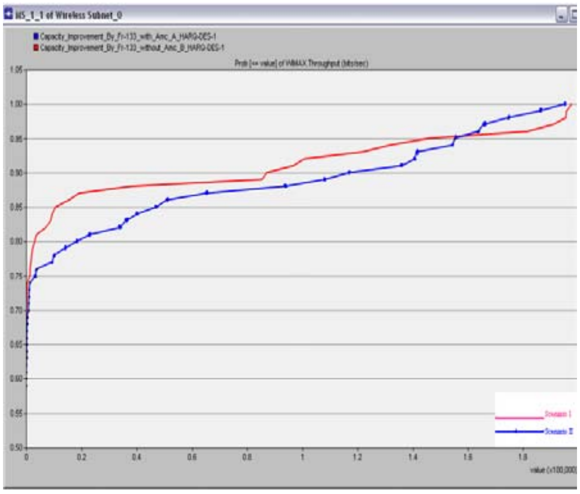


(b) Average Throughput

Fig. 4 Average SINR and average Throughput in (1×3×1) scheme with scenario I, scenario II



(a) Average SINR



(b) Average Throughput

Fig. 5 Average SINR and average Throughput in (1×3×3) scheme with scenario I, scenario II

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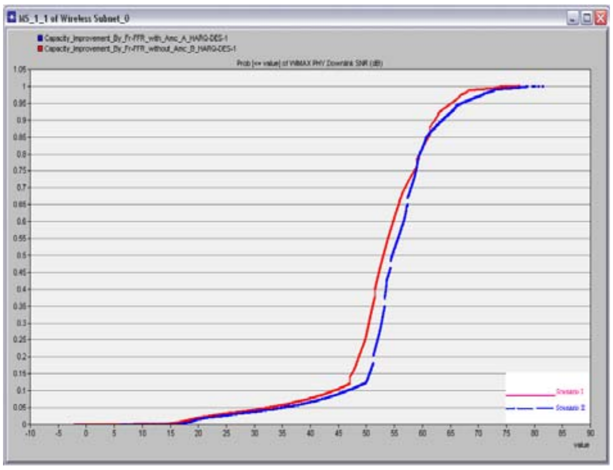
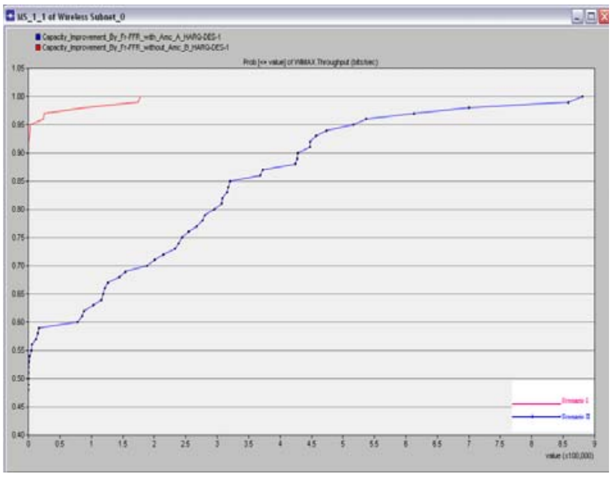
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)



*(a) Average SINR*



*(b) Average throughput*

*Fig. 6 Average* SINR and average throughput in FFR scheme with scenario I, scenario II.

## V. CONCLUSION

In this paper, we evaluated the performance of IEEE 801.16 OFDMA networks, in term of SINR and average throughput probability, using combination of various frequency reuse and conservative and aggressive AMC and HARQ algorithms as shown their values in the tables II and III, we performed our simulation by OPNET 14.5 modeler [8]. Our measure shows this simulator give us more precise results in comparison to other simulator, as shown in section IV, our experiments show that using the scenario II will achieve better throughput and SINR in comparison to scenario I. We also compared all the frequency reuse schemes and concluded that using the novel model in crowded traffic spots will give us more throughputs and less outage comparing with other frequency reuse schemes. Our studies regarding the mentioned scenarios can be applied as a practical reference for deploying in the IEEE 802.16 OFDMA systems by manufactures and service providers.

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ISBN: 978-988-19251-9-0
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)