Initiating Automated Handoff in Wireless Networks Based on Neural Network Enabled CSI Estimation

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Abstract: Machine Learning and Deep Learning algorithms are being extensively used for optimizing software defined networks. With increasing number of users and multimedia applications, bandwidth efficiency in cellular networks has become a critical aspect for system design. Bandwidth is a vital resource shared by wireless networks. Hence its in critical to enhance bandwidth efficiency. Orthogonal Frequency Division Multiplexing (OFDM) and Non-Orthogonal Multiple access (NOMA) have been the leading contenders for modern wireless networks. NOMA is a technique in which multiple users data is separated in the power domain. In the proposed approach , a machine learning based handover mechanism between OFDM and NOMA has been proposed based on channel conditions. The condition for switching or handover has been chosen as the BER of the system. A comparative analysis with existing work indicates that the proposed scheme outperforms the existing techniques in terms of SNR requirement thereby making the system more practically useful for fading channel conditions.

Keywords: Machine Learning, Deep Learning, Software Defined Networks, Automatic Handover, Quality of Service (QoS), Bit Error Rate.

1. Introduction:

Software-Defined Networking (SDN) is a revolutionary approach to network management that separates the control plane from the data plane, allowing for more flexible and dynamic network configurations. One critical aspect of SDN is the handover process, which involves transferring an ongoing connection from one network segment to another. Efficient handover management is crucial in maintaining seamless connectivity, particularly in mobile and heterogeneous environments. Machine Learning (ML) offers promising solutions for optimizing handover processes in SDN, enhancing network performance and user experienceMultiplexing remains a serious challenge even today with the limited amount of available bandwidth and the increasing number of users in cellular networks. It is estimated that with the complete onset of 5G systems globally, the number of users will increase manifold. This would require more advanced multiplexing techniques to be used for the purpose of sharing a common channel among users. Off late, OFDM has been the go to multiplexing technique and has been used in several wireless technologies. However, Non-Orthogonal Multiple Access (NOMA) has gained a lot of attention as the future of multiple access techniques. The most common multiplexing techniques used thus far have been frequency division multiplexing (FDM), time division multiplexing (TDM) and orthogonal frequency division multiplexing (OFDM). However, NOMA owing to its effective spectral efficiency is sought after as the next generation multiple access technique. As in frequency division multiplexing and time division multiplexing, the signals of different users are separated in the frequency and time domains respectively, the signals in NOMA based multiple access, the signals are separated in the power domain. The major challenge however lies in the detection of the NOMA signal at the receiving end with the separation of the different user signals in the case of multipath propagation and small scale fading effects.

2. Multipath Propagation and Channel Gain

The problem with wireless communication is the random nature of wireless channel and the mobility of users. While the random nature of wireless channel creates distortions in the received signal, the mobility of users results in fading effects and signal degradation. Typically these two effect act in conjugation and result in degradation in the Quality of Service (QoS) of the system, which can be evaluated in terms of the latency, interference and bit error rate of the system.. Practical channels do not follow the conditions for distortion less transmission given by:

$$\boldsymbol{mod(H(f) = k} \qquad \textbf{(1)}$$

Here,
H(f) is the channel frequency response
K is constant

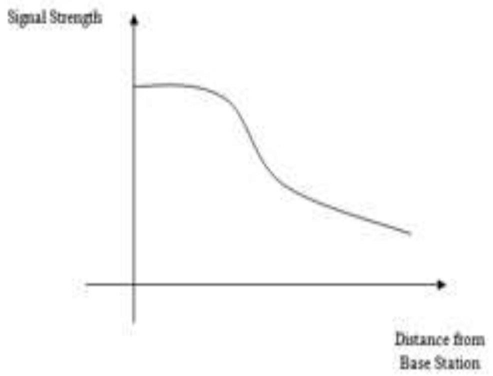

Fig.1 Signal Strength Variation in Multi-User Situations

After considering the multipath effects, it is convenient to understand the concept of successive signal detection and equalization. Practical wireless channels generally depict multi path propagation from different interacting objects (IOs) and hence show a discrete non-singular channel response.

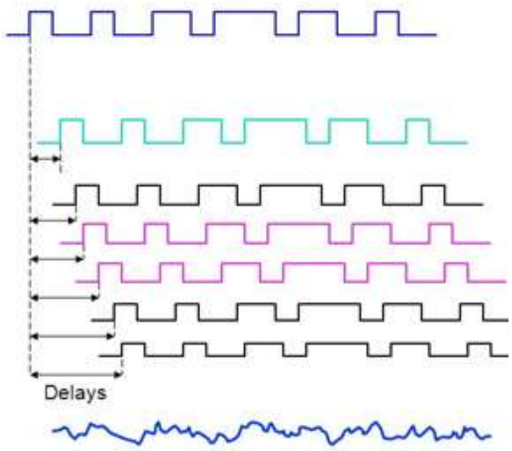

Fig.2 Inter Symbol Interference (ISI) caused due to multipath propagation

The impulse response of such a channel can be modeled as:

$$h(t) = \sum_{i=1}^{k} \delta_i(t) \qquad (2)$$

Here,
H(t) is the impulse response of the channel
δ represents the impulse function
The frequency domain counterpart of the channel impulse response is the channel frequency response H(f) given by:

$$H(f) = \int_{-\infty}^{\infty} h(t) e^{-j\omega t}\, dt \qquad (3)$$

Here,
The operator represents the Fourier Transform
$H(f)$ is the channel in frequency domain
h(t) is the impulse response of the channel
ω represents angular frequency
t is the time variable

3. Proposed Handover Mechanism based on Automatic Fallback

Typically, even with the use of equalizers and inter-leavers, noise effects can not be mitigated completely. They act as reduction mechanisms. Signal fading effects result in outages and poor quality of service. Hence alternatives to restore quality of service are sought. One of the most effective techniques is the use of handover. Vertical handovers refer to the automatic fall-over from one technology to another in order to maintain communication. In cellular communication, candidates with similar QoS performance can be considered for handover. As far as 5G and onward technologies are concerned, OFDM and NOMA are suitable candidates due to their high spectral efficiency. In case NOMA is the preferred candidate, an automatic fall back candidate can be considered to be OFDM. However, the choice of candidates to implement handover should satisfy the conditions of co-existence.

Showing that an identical SNR-BER curve can be achieved using OFDM and NOMA, thereby can justify co-existence of NOMA-OFDM for a cellular network which can lead to a possible vertical handover in case of system requirements. Non-identical BER performance in the SNR range would mean different characteristics for NOMA and OFDM thereby hindering handover. Based on the Automatic Fallback approach, choose the system BER as the metric to decide upon handover. The transceiver design is depicted in figure 3.

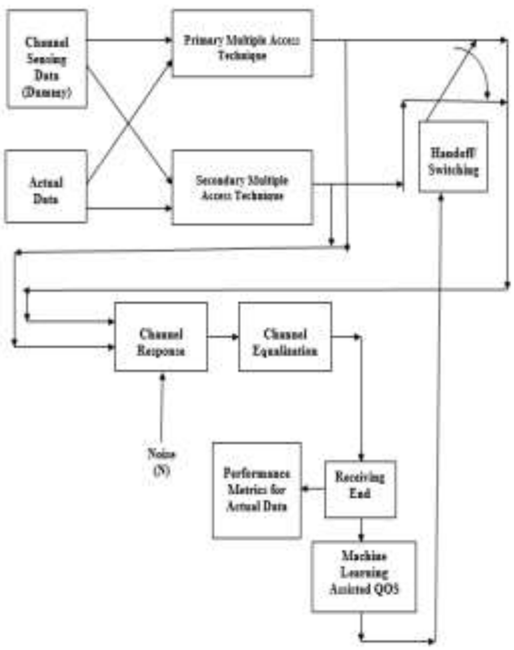

Fig.3 ML Based Handover

To estimate the channel,
Compute the error in time domain as:
$e(t) = y(t) - d(t)$ at the receiving end.
Obtain h(t) as:

$$\boldsymbol{h(t) = y(t = e(t)} \qquad \textbf{(4)}$$

This process can be applied iteratively for samples over a period 'T'. Thus the samples of the equalizer (to be designed as a filter) can be given by:

$$\boldsymbol{h(t) = \sum_{i=1}^{N} h_i(t)} \qquad \textbf{(5)}$$

Finally, convert h(t) in the frequency domain by evaluation of:

$$\boldsymbol{H(f) = \int_{-\infty}^{+\infty} h(t) e^{-j2\pi ft} dt} \qquad \textbf{(6)}$$

For reception of the signal, evaluate the following:

$$\boldsymbol{S_i = sign\{real[S_{composite}(t)]\}} \qquad \textbf{(7)}$$

$$\boldsymbol{S_q = sign\{real[S_{composite}(t)]\}} \qquad \textbf{(8)}$$

Here,
I represents the in-phase component

To, estimate the BER of the system for NOMA and OFDM,

$if\ (BER_{NOMA} < BER_{OFDM})$
{
Choose NOMA as the transmission technique
$else$
{
Fall back to OFDM
}

It has been discussed that a major challenge of NOMA based multiple access technique is the fact that small scale fading effects and multipath propagation make the amplitude of the power variable at the receiving end. This results in difficulty of separating the signals of different users with equal reliability. The metric for obtaining equal reliability and quality of service (QoS) is the bit error rate (BER) of the system which is mathematically defined as:

$$\boldsymbol{BER = \frac{Number\ of\ Error\ Bits}{Total\ Number\ of\ Bits}} \qquad \textbf{(9)}$$

Moreover, the BER depends on the SNR of the system mathematically which is given by:

$$\boldsymbol{P_{err} = f\ \{Q\left[\sqrt{\frac{S}{N}}\right]\}} \qquad \textbf{(10)}$$

Here,
Q represents the Q function
S represents signal power
N represents noise power

There are several Machine Learning techniques that can be applied to handover management in SDN. Supervised learning models, such as decision trees and support vector machines, can be trained on labeled data to classify handover decisions based on specific network parameters. Unsupervised learning methods, like clustering algorithms, can identify patterns in network behavior that are not immediately apparent, allowing for more adaptive handover strategies. Reinforcement learning, which learns optimal actions through trial and error, is particularly well-suited for dynamic handover scenarios where the environment is continuously changing. Second, ML algorithms can adapt to changes in network traffic patterns and user mobility, providing more resilient and flexible handover solutions. Third, by automating the decision-making process, ML reduces the burden on network administrators and allows for more scalable network management.

4. Experimental Results

The typical multi user detection mechanism has been developed in the proposed work. The system has bene designed on Matlab.

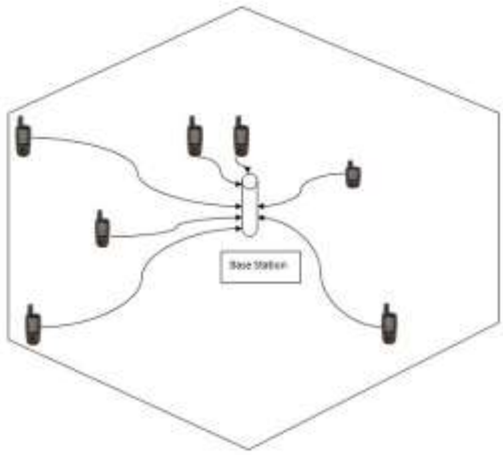

Fig.4 A typical MUD scenario.

The multipath propagation mechanism in the system generally comprises of:

1) LOS (ideal)
2) MPC for near users
3) MPC for far users.

The scenario is depicted in figure 5.2

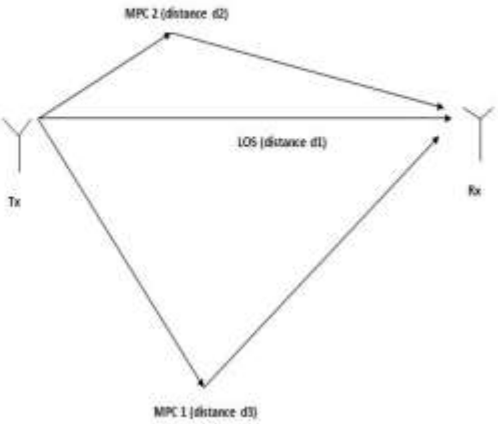

Fig.5 Multi Path Propagation Model

Here,
LOS designates Line of Sight
MPC designates Multi Path Component
The significance of the multipath propagation model is the fact that often the amplitude at the receiver keeps varying due to the fact that small scale fading is prevalent at the receiving end.
In this case,
LOS travels d1
MPC 1 travels d2
MPC 2 travels d3
Also,
d1<d2<d3
Different users send their signals at different power levels. In general, the user farthest away from the receiver would face the most severe fading. On the contrary, the user nearest to the base station would face the least fading, Hence, the users can be categorized into 2 major categories which are:

1) **Near User**
2) **Far User**

The near and far user situation can be differentiated based on the path loss factor. The noise condition considered in this case is AWGN with a constant noise psd for all frequencies. Mathematically,

$$Noise_{psd} = \frac{N_0}{2}\ \forall f$$

Here,
psd represents the power spectral density
f represents frequency
$\frac{N_0}{2}$ represents the two sided AWGN psd

Based on the automatic fall-back approach, choose the system BER as the metric to decide upon handover. For the near and far user scenario, we obtain the overlapping BER curves. The lesser among the two BER curves would be the technology to use. The results are presented subsequently.
:

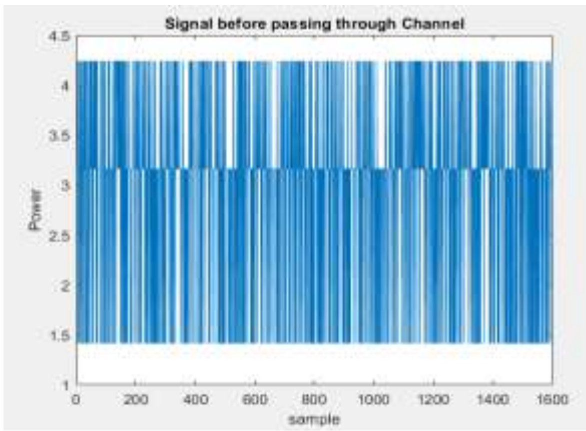

Fig.6 Transmitted binary signal

The generally used Additive White Gaussian Noise (AWGN) model does not adequately represent the channel for these modern applications. Moreover, the Line-Of-Sight (LOS) path between the transmitter and the receiver may or may not exist in such a channel. White noise is added to the channel to emulate a practical Additive White Gaussian Noise (AWGN) condition given mathematically as:

$$Noise_{psd} = \frac{N_0}{2} \; \forall f$$

Here,
psd represents the power spectral density
f represents frequency
$\frac{N_0}{2}$ represents the two sided AWGN psd

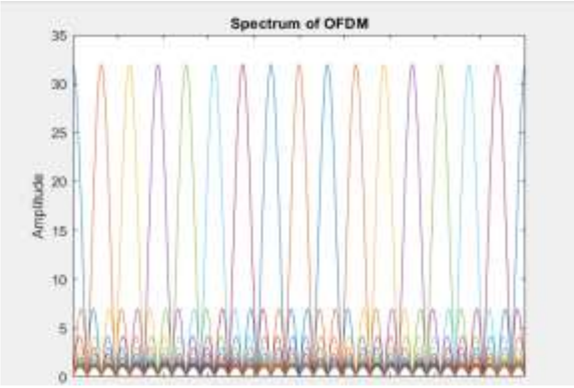

Fig.7 Spectrum of OFDM

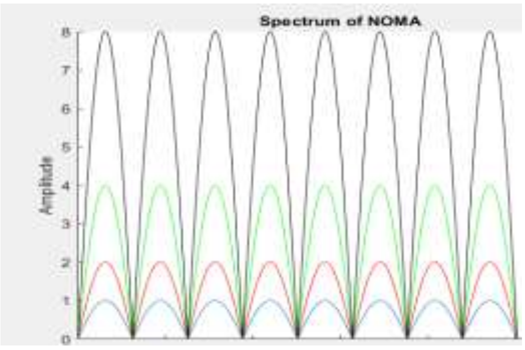

Fig.8 Spectrum of NOMA

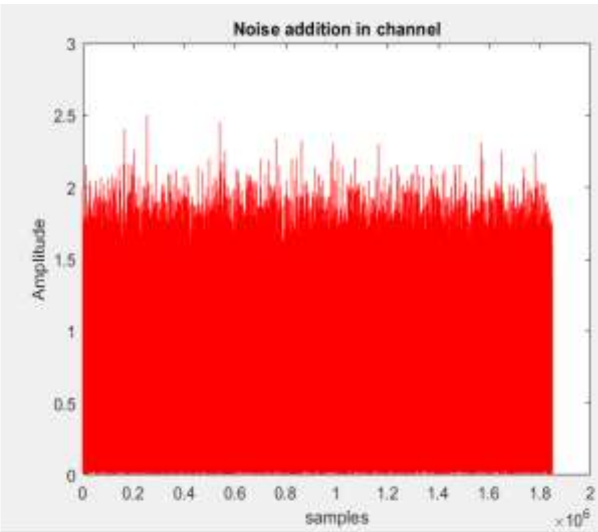

Fig.9 Addition of Noise in the Channel

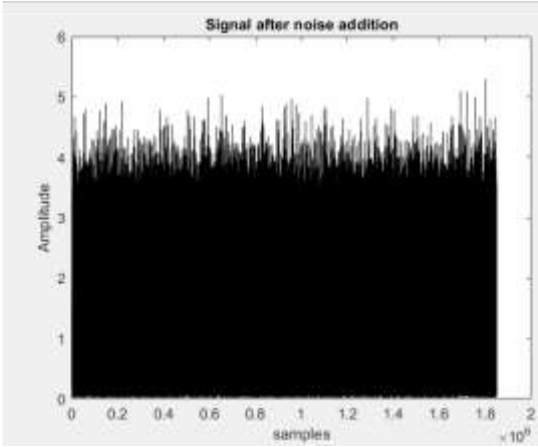

Fig.10 Signal after passing through channel

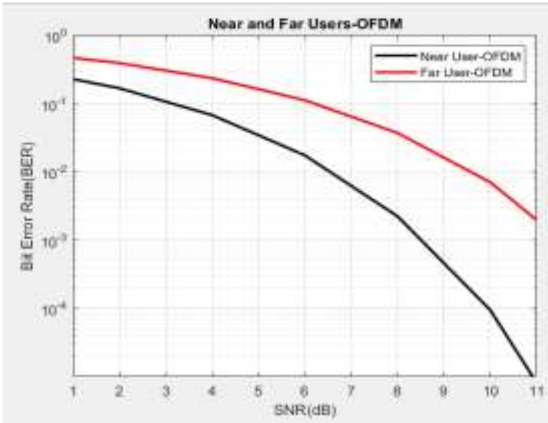

Fig.11 Near and Far user condition for OFDM

The figure above depicts the BER performance for near and far users in OFDM. It can be seen that the far users have a higher BER compared to the near users.

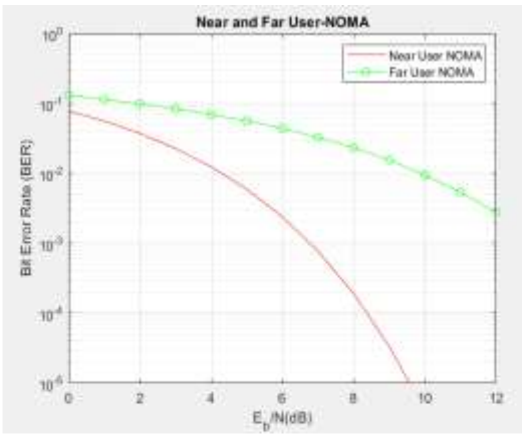

Fig.12 Average user without proposed algorithm

The figure above depicts the BER performance for near and far users in NOMA. It can be seen that, as in the case of OFDM, for NOMA too the far users have a higher BER compared to the near users.

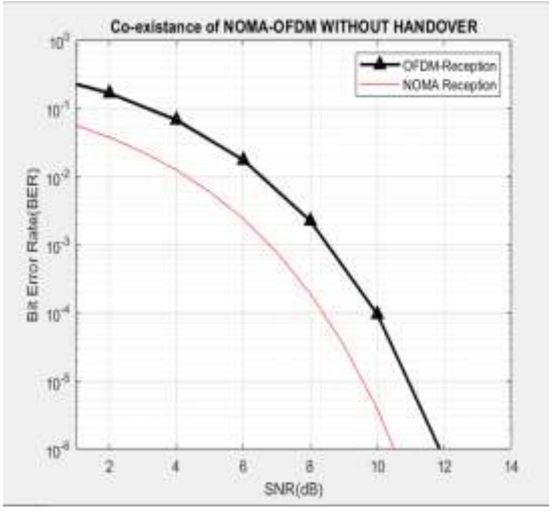

Fig.13 Co-existence of NOMA-OFDM

The figure above shows the BER condition for the co-existence of NOMA and OFDM without the handover condition as the primary modulation scheme (NOMA) has a low BER metric value for the entire range of SNR.

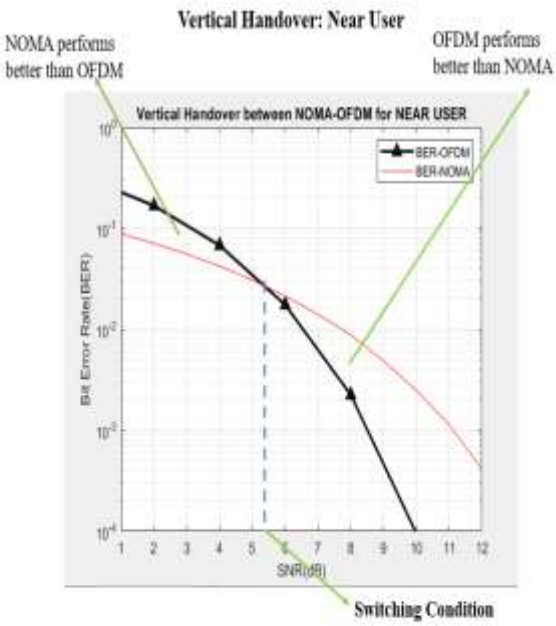

Fig.14 Vertical handover for near user condition

The figure above shows the condition for switching among NOMA and OFDM for the near user scenario. It can be seen that prior to the intersection point, NOMA performs better while after the intersection point, OFDM performs better in terms of system BER.

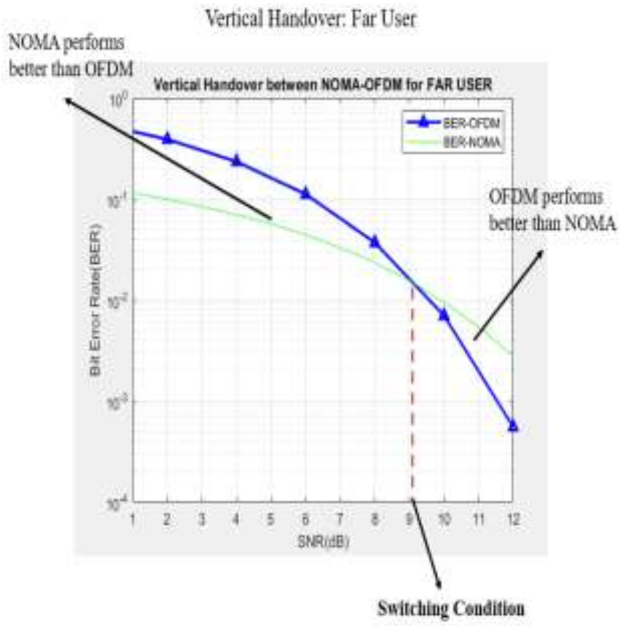

Fig.15 Vertical handover for far user condition

The figure above shows the condition for switching among NOMA and OFDM for the far user scenario. A similar pattern is seen with the difference that the BER now falls slower compared to the near user condition implying the fact that SNR is relatively less.

Conclusion

It can be concluded from previous discussions that automatic fallback is necessary for practical wireless systems as multi-path propagation, fading effects and noise result in signal degradation and increase in the bit error rate of the system. In this work, a system is designed which employs automatic fallback between two contenders which are chosen as NOMA and OFDM based on Machine Learning. The BER is chosen as the switching parameter. It has be earlier shown that OFDM and NOMA can serve to be competing or parallel contenders for transmission. It has been shown that in case of non-intersecting BER curves, the condition remains to be that of non-handover since one of the techniques for transmission continuously outperforms the other in terms of the performance metric (BER). In case of handover, concurrent BER curves for OFDM and NOMA intersect to create a point of intersection. The region prior to and subsequent to the intersection point govern the technology to be used.

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