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Towards Fog-Relay Selection Strategy for Distributed 5G Networks

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Abstract

THe demand for Cyber-physcal computing requirements beyond 4G spectrum such as increased capacity, low latency, energy efficiency, resource provisioning, reliable data rate, and overall quality of service (QoS) has fuelled the fifth generation (5G) Fog-relay network innovation. The overall benefits of Cloud computing, Internet of Things (IoT), Edge computing (EC) and the recent Osmotic computing (OC) cannot be satisfied without an efficient relay cooperative communication domiciled in distributed 5G Fog network. To meet these demands, deliberate improvements were introduced in existing cellular network infrastructure. First, the paper reported findings on literature survey of 5G relay communication network architecture, relay classification, as well as parameter selection for device-to-device communication (D2D). Second, Single/multiple relays for cooperative communication are discussed while presenting perspectives on typical relay-assisted cooperative network. Third, 5G network relay Use-Cases and its expectations is highlighted. Fourth, 5G Fog network K-clustering relay algorithm for the proposed relay selection scheme is introduced for Fog-data offloading. Monte Carlo simulation model is used to derive the average data values plotted in the OMNeT++ experiment. Furthermore, the performance of a two hop relay transmission scheme in an edge-Fog scenario is discussed. Metrics such as Threshold-distance, threshold SINR and threshold-distance-SINR techniques are used for the relay selection evaluation. Results showed that the accuracy of the proposed relay selection technique has better performance compared to threshold-SINR, threshold-distance and the threshold SINR-distance techniques for all the different numbers of user devices. It was observed that the Root Mean Squared Error (RMSE) of proposed technique has lowest error relative to other techniques regarding data forwarding. The research offers insight into 5G-Fog distributed network for researchers and industry practitioners.

Keywords: *5G-Fog Networks, Cloud Computing, Machine learning, IoT, Cyberphyscial Systems*

1. Introduction

1.1. Background

Today's wireless networks are reaching their limits due to the exploding demand for mobile data, driven by increased infiltration of smart devices, enhanced hardware and the desire for ubiquitous high speed connectivity. It is expected that the future 5G network will accommodate this network capacity through enhanced performance, higher data rates and better spectral efficiency. The IoT/everything technology, (including edge, Fog, cloud and Osmotic computing) has given rise to massive objects connectivity. This will contribute to the demand for more spectrum and bandwidth.

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To cater for this, millimetre wave (mmWave) network (in the frequency band of 20 - 100 GHz) has been proposed as a viable technology for 5G communication systems [1]. The challenge with mmWave network is the high rate of propagation loss and signal blockage which lowers the data rate. Technologies like beam-forming and directive antennas have been proposed to tackle these issues. Though directive antennas are designed to mitigate propagation loss, they leave another problem of signal blockage. Beam-forming is employed to partially rectify signal blockage but consumes significant time during neighbour discovery. Relay selection schemes help to reduce the propagation loss as well as the signal blockage issues in mmWave network [2].

Cooperative communication (CC) via Fog relay selection is one of the requisite techniques to improve coverage, network capacity and reduce power consumption in the network. Its success however hinges on the selection of the best relays for the network considering the dynamic network requirements and varying user needs.

Different relay selection schemes have been proposed by researchers to improve system performance, but one point that has multiple views is, the best number and kind of parameters to be applied in the selection process.

Also, most of the existing schemes have been based on 4G networks and employ fixed, single parameters for relay selection.

In addressing this, a two-phase Fog-reelay transmission is considered in this work. The first phase occurs between the source and the candidate relays, and involves the selection of a set of “reliable relays”. The second phase occurs between the reliable relays and the destination, and could involve the selection of the “best relay” for transmission, or use of the multiple relays to achieve cooperative spatial multiplexing. This work focuses on the first transmission phase, and makes few significant contributions within distributed 5G Fog network. First, an intelligent and dynamic relay selection using k-means clustering is proposed to group users based on the available features. This assumes that relays and non-relays form distinctive clusters in the feature space. The algorithm is then compared with fixed parameter relay selection using the distance and signal-to-interference-plus-noise ratio (SINR) parameters.

While the idea of integrating relays in a cellular network is not new, only recently has the study on the advantages and requirements of Device-to-Device (D2D) communication in 5G cellular networks gained grounds. The D2D or device tier network allows mobile devices to act as transmission relays forming a large ad-hoc network with spatial diversity benefits [3]. The current 4G network standard already has integrated fixed terminal relaying to achieve cooperative communication. The fixed relays, or base stations which boost coverage, will not be sufficient to meet the mobility needs of the 5G network users. To take full advantage of cooperative communication, devices such as mobile phones, laptops and tablets must be included as relays.

The concept of D2D communication was introduced to help offload data from central base station (BS) by creating a direct communication link between nodes. D2D has been in existence in technologies like Bluetooth and Wi-Fi. However, for cellular network, the serving base station (eNodeB) has historically been the central point of communication and radio resource sharing.

With Proximity Services (ProSe) and Release 12 introduced to 3rd Generation Partnership Project (3GPP) [4], the User Equipment (UE) can discover and communicate with other UEs with limited involvement of eNodeB [5]. In the 3GPP, items included are support for Proximity Services (ProSe), MBMS enhancements, Machine-to-Machine (M2M) applications, Self Organizing Networks (SON) and interworking between HSPA, Wi-Fi and LTE [4].

In 5G networks, there will be an increase in context aware services, location discovery and communication with neighbor; the number of indoor services is expected to be four times more than outdoor services [3]. The availability of device relaying will help to reduce the cost of communication in such settings. Fog relays act like proximity service providers that enable energy efficiency, spectral

efficiency and reuse of frequency. Relay-assisted D2D communications have been suggested to boost the coverage and the transmission capacity of a wireless network [6], [7] and [8].

The main research trust focused on how Fog relays should be selected to meet the dynamic network requirements of a 5G Fog distributed network. The specific questions are listed below:

i. What parameters should be used for selecting Fog relays?
ii. What optimal number of parameters would ensure efficient Fog relay selection?
iii. When is Fog relaying actually necessary?

1.2. Research Contributions

The research contributions in this paper include:

i. To highlight the current relay selection schemes in existing cellular and ad-hoc networks. A critical evaluation of relay selection capabilities and its limitations with respect to 5G network is presented.

ii. To Study the benefit and expectation of relaying in 5G networks. Following the ongoing efforts to set up a standard for 5G networks, the expectations of data rate, spectral efficiency and bandwidth will determine the requirements for a 5G Fog relay. This work seeks to achieve this objective by comparing the state of the art in present relay assisted network with the 5G network.

iii. To evaluate Fog relay selection scheme for 5G Fog network using K-clustering algorithm. In this regard, the basic knowledge of machine learning (ML) algorithm will be applied to design 5G Fog relay selection scheme. Network simulator software, Omnet++ will be used to generate data required for the ML algorithm. The performance of the proposed algorithm will be evaluated in terms of its accuracy and mean squared error against other selection techniques used in previous literature.

The paper is organized as follows: Section 2 introduces a summary of relay selection schemes/classifications. In section 3, we propose a relay selection framework involving Fog-data offloading for device-centric transaction in a dynamic Fog network scenario. Section 4, describes the performance evaluation metrics considering the 5G Fog model for proposed K-means technique with SVM as well as other selection policies. Section 5, describes Omnet++ experimental result with discussions. Conclusion and future directions is made in Section 6.

2. Relay Selection Schemes

2.1. Relay Classification in Wireless Networks

A relay can be described as a node which receives signals from base station (or eNodeB), amplifies and sends it to the user equipment [9]. The 3rd Generation Partnership Project (3GPP) has defined two types of relays based on the control mechanism, namely, type I and the type II relays as shown in Figure 1. The type I relay functions like an eNodeB and aims at improving coverage. The relay performs its own resource allocation and communicates with the host eNodeB through a wireless backhaul [10]. Types II relays focus mainly on improving capacity and are suitable for multicast cooperative network. These relays are fixed terminal relays which are less adaptable to the 5G cellular network environment. For the 5G network, there may be cases where fixed relays are unavailable in a network and mobile users act as relays to reduce the cost of deploying infrastructure for fixed relay stations. Also, the increasing context aware services that require location discovery and neighbourhood communication makes device relaying a more desirable consideration for 5G network. Relays have been classified in literature based on several attributes like device type, capacity, function, selection technique, as summarised in Table 1. Depending on the type of device,

the relay can be a mobile relay station (MRS), fixed relay station (FRS) or user-assisted relay. In user-assisted relaying, the idle UEs serve as relays, thus providing more flexibility than the fixed relays and reducing the cost of RS deployment. Elkotby and Vu [11] analyzed the system-wide performance of user-assisted relays when deployed in a cellular network.

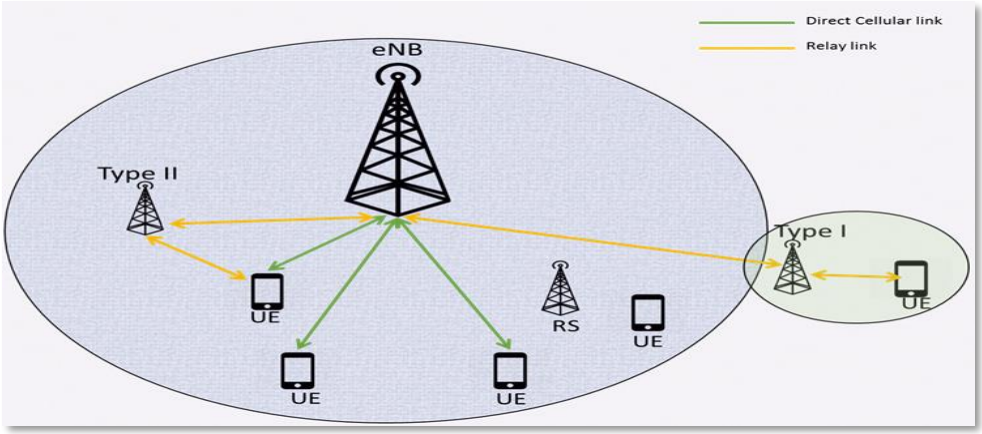

Figure 1: 4G Relay network.

Relays have also been described in terms of the deployment context. In outdoor environments, users at cell edge have less throughput due to pathloss between the UE and eNodeB. Examples are users living in rural areas or locations where the coverage of the network is low. In indoor setting, several nodes communicate with each other as a mobile ad hoc network (MANET), e.g. a home entertainment system or a smart home network. In a heterogeneous network (HetNet), a small BS can act as relay serving a small cell or coverage area. The relay is similar to the specified 3GPP type I relays due to its function as an eNodeB (eNB) serving UEs within its coverage and communicating with the macro BS serving the bigger network. Table 1 summarizes wireless network relays based on classification attributes, and descriptions.

Table 1 : Relay classification for wireless network [12].

Attribute	**Classification**	**Description**	**References**
Device type	Terminal relay	Low power base station e.g femtocell, eNodeB, picocell	Tehrani, Uysal and Yanikomeroglu [3]
	Device relay	User equipment e.g. smartphone, laptop, tablet	
Frequency	In-band	BS-Relay link and Relay-destination link on same carrier frequency	Chen and Zhao[13]
	Out-of-band	BS-Relay link and Relay-destination link on different carrier frequency	
Mobility	Fixed	Relay is fixed at a location e.g small cell RS	Nomikos, Skoutas, and Makris [14]
	Mobile	Relay is mobile e.g cell phone, vehicles	
Number of hops	Multihop	The destination UE receives information from the source link and the relay link	Fantini Sabella and Caretti [9]

	Two-hop	The destination UE receives source message only through the relay link	
Transmission mode	D2D	UEs act as transmission relays for each other	Ma. et al. [15].
	Cellular	Relay is a small cell BS	
Location	Transparent	Located within the coverage of the BS	Bhute and Raut [16]
	Non-transparent	Located outside the coverage of the BS	
Selection technique	Threshold	Based on threshold value of parameters	Onat et al. [17].
	Intelligent	E.g. dynamic threshold and Fuzzy AHP, Machine learning	Lu, Chiu and Chen [18]
Number of selection parameters	Single	A single parameter is considered during selection	Ikki and Ahmed [19]
	Multiple	Several parameters are considered during selection	Mishra, Pandey & Biswash [20].
Selection decision-maker	Network-assisted	Base station / eNodeB decides the relay	Sankhe et al. [21].
	Device-centric	Device decides	Mastronarde et. al [22].
Forwarding scheme	Amplify-and-forward	Relay amplifies received signal and forwards to destination in 2nd phase	Yang et al. [23].
	Decode-and-forward	Only relays which correctly decoded the source message can participate in forwarding	
Optimisation	Random relay	Selection strategy does not require feedback or channel state information (CSI)	Deng and Klein [24].
	Best/optimal relay	The relay having the max/min value of a link quality is selected	Kara et al.[25],[42]
Deployment scenario	Proximity communication	A D2D relay UE assists a D2D pair to communicate	Da Silva et al.
	Coverage/range extension	A D2D relay extends communication from a UE to the eNodeB	

2.2. Choosing Relay Selection Parameters in Wireless Networks

Several techniques for relay selection based on varying parameters have been proposed in literature. Table 2 summarizes the various parameters that relay nodes have been chosen against, their selection method, objective and limitations. In most cases, the selected relay(s) may be required to fall within a given threshold or may be selected based on maximum/minimum value of a

parameter among a set of other relays. Some commonly used metrics for relay selection are signal-to-noise ratio (SNR), SINR, data rate, throughput, energy efficiency, and reliability.

One prevalent research problem is the decision on which parameter(s) is best suited for Fog relay selection. Most authors have considered relay selection based on a fixed parameter. In a case of a best relay selection, the relay will possess the maximum or minimum value of such parameter among all available relays. In [27], a distance-based algorithm is proposed such that the relay closest to the destination is chosen as the optimal relay. However, the use of distance alone to choose relay may not be effective and does not reflect channel state information (CSI) as differences in received signal's Signal-to-Noise ratio (SNR) may result from attenuation, shadowing and interference. The authors in [17] performed relay selection by comparing source-relay SNR or destination-relay SNR to the threshold SNR. However, for a two-hop transmission reliability is not guaranteed where the relay resides at distances asymmetrical to source and destination. The threshold based relay selection also has its own limitations. Using distance threshold for instance, the algorithm can select a relay node closer to the source but farther from the destination for a two-hop transmission [28].

Considering the Figure 2, if UE1 has higher SNR than UE2, it will be selected as a relay, whereas it is closer to the source and farther from the destination. In [29], the authors found out that given the nature of 5G network with dynamic network scenarios and varying user needs, a single parameter cannot fulfil the user requirement. In their work, they applied a weighting method to decide on the best relay using multiple parameters (SNR, SINR, data rate, throughput, buffer space, energy efficiency, and reliability).

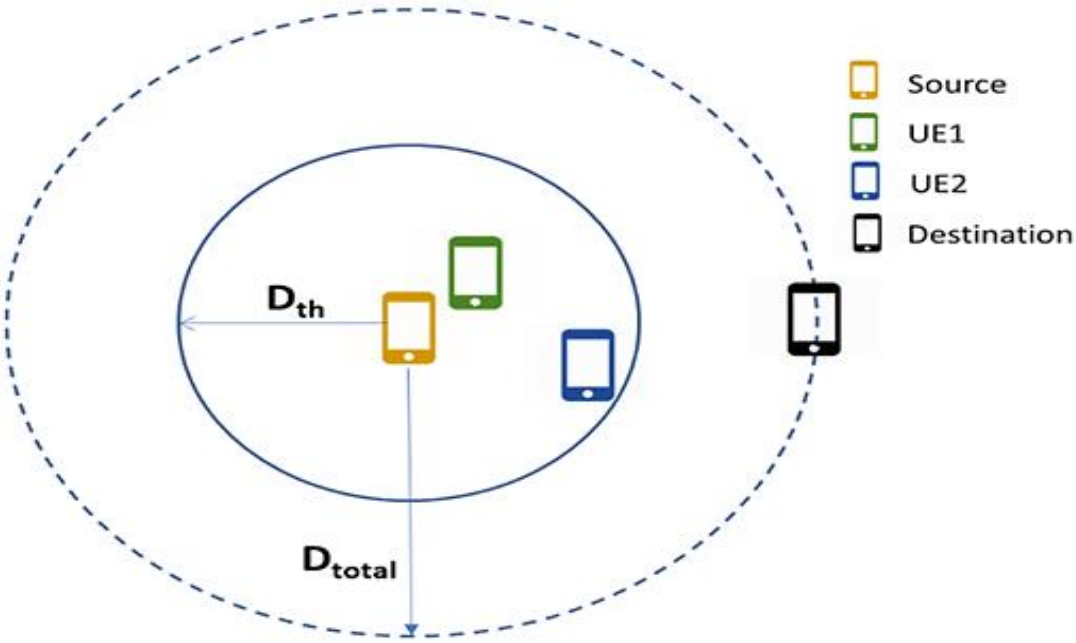

Figure 2: Problem with Threshold Relay Selection Method.

The weight was assigned to each parameter based on the application and network scenario. However, the network scenarios discussed in [29] are in no way exhaustive for 5G applications, and may thus prove inefficient for outlier cases. Also, it may not be realizable to have all these parameters available to the network in all scenarios. Table 2 outlines the efforts based on relay selection parameters.

Table 1. Different parameters for relay selection.

References	Parameter	Measure	Number of relays	Selection method	Benefit/ objective	Drawback
Onat et al. 2010 [17]	SNR	Threshold	Single	Destination selects relay with best relay-destination SNR at second phase	To minimizes the end-to-end bit error rate (BER) of threshold-relaying	Complexity of end user is higher, more power consumption
Qin and Xiao 2016 [30]	SINR	Maximum	Single	Source user selects relay with highest predicted SINR over the source to relay link	considers the presence of the co-channel interference	Hard (if not impossible) to measure the exact SINR value.
Nourizadeh, H., Nourizadeh, S. and Tafazolli 2006 [31]	Signal-to-Interference Ratio (SIR)	Maximum	Single	Mobile station select among the RS with whom it experiences the highest SIR.	Improve system performance	optimizes performance based on UE not considering the overall system performance
Sankhe et al. 2015 [21]	Bit-Error-Rate (BER)	Minimum	Multiple	eNodeB selects relays with minimum BERamong the predicted willing users to form a virtual MIMO	To find good end to end path	Overhead due to processing of a large volume of pre-known data
Wang et al. 2008 [32]	Received Signal Strength (RSS)	Strongest	Single	Two-hop transmission adopted to deliver data if the RSS from RS is stronger	To improve link reliability	Can reduce system capacity in two-hop transmission
Hajjar et al. 2017[33].	Path loss	Similarity	Multiple	K-means clustering used to cluster nodes based on their path-loss similarity	Better than distance as it gives better estimation of the link quality	Contributes little in affecting diversity-multiplexing in high SNR system
Chen, M et al. 2009 [27]	Distance	Minimum	Single	Relay closest to the destination is chosen	Smaller end-to end delays, facilitates fast and reliable packet delivery	Does not reflect CSI
Yang et al. 2010 [35]	Energy consumptio	Minimum	Single	BS selects relay which minimizes	improves energy efficiency	Does not consider the

	n			energy consumption		overall system performance
Mishra et al. 2016 [20]	Buffer space	Threshold	Single	Device chooses the best relay for D2D	Considers buffer that reduces the network throughput	More battery consumption, interference, due to dependency on multiple devices
Mahama and Asiedu 2017 [36]	Throughput	Maximum	Single	No CSI required at source or relay node. Depends on the Distances from source to relay and from relay to destination	to achieve better effective transmission rate	Selection must occur at optimal relay location to maximize the system capacity

2.3. Single Vs Multiple Relays for Cooperative Communication

Most of the relay selection techniques considered in literature deals with selecting a single relay among multiple users. In a two-phase transmission, the source node first selects the relay from a group of UEs, and the relays subsequently forward the source information to the destination in the second stage as illustrated in Figure 3. Selection of an optimal relay has been shown to achieve full diversity such as is achievable through multiple relays [37].

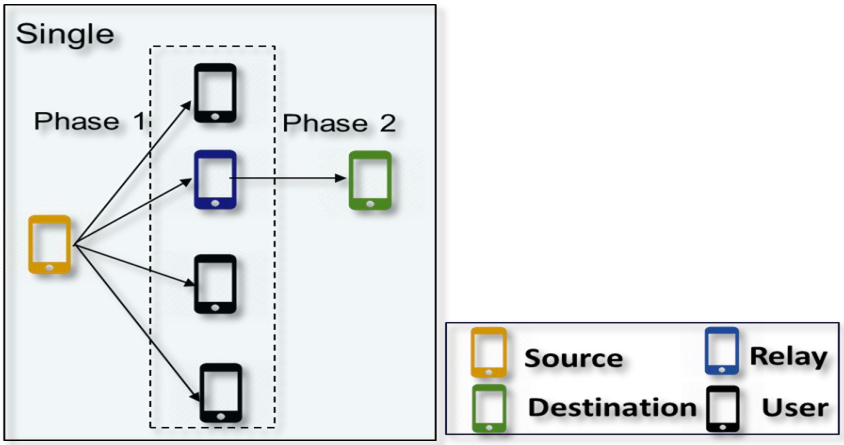

Figure 3: Single Relay Selection Illustration in Two-hop transmission [37].

On the other hand, some researchers have proposed the selection of multiple relays in a network. Three major application scenarios of multiple relays have been identified from studies. One, the relays can be used to forward the same message from the source to destination in order to improve transmission reliability and achieve cooperative spatial multiplexing [38]. Two, the selected relays, known as the “reliable relays”, are chosen at the first phase of the transmission, and then the destination selects the “best relay” based on a pre-defined parameter [17]. Three, each of the relays can act as cluster heads through which communication is established between the source and the other UEs in each cluster [33]. Figure 4 shows the interaction between source, relay and destination for the three scenarios in (a), (b) and (c) respectively.

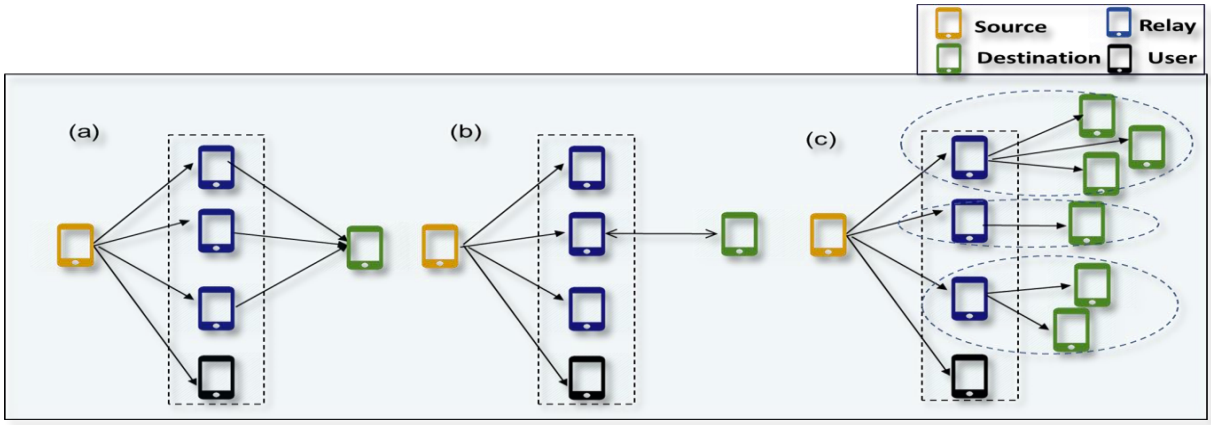

Figure 4: Multiple Relay Selection Illustration in Two-hop transmission.

2.4. Typical Relay Assisted Cooperative Network

A typical 5G relay-assisted network consists of fixed and mobile relays as shown in Figure 5. The main scenarios for proximity communication and coverage extension are illustrated. The UE2 is at cell edge and RS2 serves as a coverage extension relay station that transmits information from eNodeB to the device through cellular links. UE3 can communicate with UE4 via D2D links. Fixed relay stations are placed as cell cluster heads relaying messages to a group of UEs within its coverage. The cells can be micro cells, pico cell or femto cells as applicable in 5G network. The network supports single-hop and multi-hop D2D communication between source-destination (S-D) or direct communication with base station when in cellular mode. UE5, UE6 and UE7 engage in multihop communication via D2D links. Through this cooperation, a virtual MIMO can be formed for coverage extension through base station distributed beam-forming [18]. RS1 is a 3GPP type I relay station (RS) as it is used for proximity communication while RS2 is a type 2 relay for coverage extension to UE2. The eNB is responsible for resource allocation to smaller relay stations and UEs linked to it.

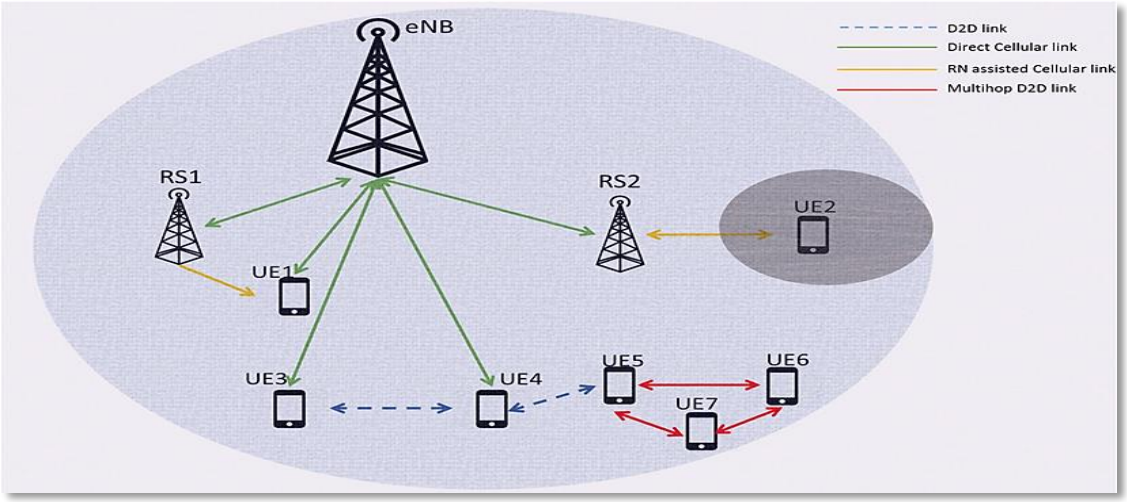

Figure 5: 5G Network and Cooperative Communication Illustration.

2.5. 5G Network Relay Use Cases

The authors [6] opined that D2D quality is affected by the distance and quality of D2D link. The authors show that relay assisted transmission enhanced performance of the network in terms of its transmission capability and power efficiency. In [39], the authors presented massive multiple-input-multiple-output (MIMO) and mmWave communication as key technologies for the deployment of 5G cellular network ultra-dense network and identified a need for a new multihop relaying scheme for this network. Most of the communication in 5G network will be indoor, increasing the need for relays

in the network. The limitation in the use of MIMO in current 4G network creates a very good case for virtual MIMO formation where relaying becomes necessary to achieving virtual spatial diversity. With an expected exponential increase in the number of users of mobile devices, the distance between users will decrease, creating a thriving environment for D2D relaying. UEs at cell edge will benefit from this type of communication without need for extra infrastructure.

By dividing the communication link into shorter distances, relays help to achieve an overall improved capacity and distance gain. They reduce the cost of deployment of macro base stations and help to overcome obstacles in mmWave network. Relay nodes help to improve coverage by ensuring high SNR for UEs at cell edge. Thus, relays should be placed in optimal positions where the UEs will benefit maximally and where coverage radius will be increased.

In [40], the authors analyzed the two-fold gain of D2D communication; one, the shedding of downlink cellular traffic to D2D; and two, the reuse of uplink resources. In [41], the work describe the usefulness of relay when communicating with devices at cell edge to improve network coverage area. It is clear that the mobile Ad hoc type network configuration, specified for the 4G, is expected to become a key component of the 5G network. This network, arbitrarily formed by mobile nodes, can operate as a standalone or a part of a larger network. As a standalone, the nodes engage in D2D communication and do not need the assistance of eNodeB. To extend communication to devices outside the network range, a relay node is required. Based on the features outlined in Table 3, the 5G network relay is likely to see increasing number of device-centric, mobile, intelligent and multiple parameter relays capable of D2D communication.

Table 2. Expectations for a 5G relay network.

Expectations	Motivation	References
Large scale deployment	To improve the coverage and throughput	Ma et al. [15]
Shortened communication range	Ubiquitous use of smart terminal devices, mmWave network	
Increased interaction frequency between users	Wide use of smart terminal devices	
Selection based on multiple parameters e.g SINR, SNR, reliability, buffer space, residual battery power	Better solution for energy efficient and reliable communication	Mishra, et al. [20]
Larger number of relays	90% of future communication will be indoors	
Virtual spatial diversity achievable through relays	Physical limitations in use of multiple antennas in current MIMO systems	Kara et. al. [42]
Virtual cell formation	Reduce frequent hand-overs, mitigate interference and high channel capacities	Sankhe et al. [21]

2.6. Cooperative Communication Network Deplyment Models

Furthermore, research on the simulation of practical deployment scenarios for relaying in 5G network is still in its infancy, with most being more focused on coverage analysis for mmWave network. In [26], the authors proposed a scheme to improve energy efficiency in cellular network using D2D-capable relays in two scenarios, namely proximity communication and coverage extension. In the former, the D2D relay assists communication between a D2D pair; while in the latter, the relay transmits data coming from an out-of-range UE to the eNodeB. The paper [46] used global network information from the nodes to determine the appropriate relaying hops. The information contains distance between nodes, direction of antenna and traffic load. Swain et al.[47] considered several D2D and orthogonal cellular users uniformly distributed around the eNodeB. A hundred UEs were selected and the throughput was compared against selected number of users for both cellular and D2D links. Andreev et al. [48], assumed the transmitting users are uniformly distributed within a circle. They focused on an area of interest where a set of D2D and cellular users are co-located in a small region of radius 100m. They performed their evaluation using Omnet ++ simulator. Bhushan et al.[49] illustrated a traffic offloading scenario where a device with better geometry to the eNodeB is selected as a relay.

Few of the research on cooperative communication have applied Omnet++ network simulator for model design or evaluation. Hähner et al. [50] designed a network where UEs can engage in multihopcommunication using route discovery service maintained at the eNodeB. Sliwa and Wietfeld [51] designed a network model for mobile robotic networks using smarm of autonomous agents performing exploratory task in a defined mission area. Similar to this work, Mishra and Pandey [20] applied Omnet++ for mode selection in dynamic network for 3 scenarios – cellular mode, D2D mode and Cellular-D2D mode. Using SimuLTE, an Omnet++ based simulator, Vallati et al. [52] demonstrated how D2D offsets the load on microcell and reduces application delay compared to a Device to Infrastructure (D2I) scenario in a smart home IoT deployment.

2.7. Consideration for Machine Learning in 5G Cooperative Communication (CC)

Since requirements for relaying in 5G is more complex than in 4G, it is advantageous to develop a network that can adapt to different network scenarios in 5G network. Complicated environment which cannot be explained via simple mathematical models will require complex algorithms for which machine learning can provide low complexity estimations, Alsheikh et al. [53]. Several relay selection algorithms have been proposed in previous research. However, most of the algorithms and models consider a point-to-point communication model consisting of a single source, relayand destination. These rules and algorithms do not consider the mobility of users and the cooperative nature of future network where interactive decisions will need to be made by base stations both in the uplink and downlink transmission (Wickramasuriya et al. [54].

A common research problem is in determining the best approach and entity to run the algorithm. Lu, et al [18] chose the candidate relays to run the pre-trained support vector machine (SVM) so as to determine whether to participate in packet forwarding or not. In [42], the decision is two-fold using received SNR as a measure of link quality. First, the S-R link quality is weighed at the relay and those received SNR is above a given threshold are added to a decoding set. Then, at the destination, the R-D link quality is evaluated and the destination selects the relay that gives the highest received SNR value. Lets look at various ML approaches for 5G CC

- ***Support Vector Machine***

Support Vector Machine (SVM) is a supervised ML algorithm which is used to resolve classification problems. It has been widely studied for different application areas in cooperative communication. Using SVM, Wickramasuriya et al. [54], predicted the optimal next base station a mobile user associated with based on Received Signal Strength (RSS) values. Michaelis et al. [55] predicted the

next cell that a mobile node would connect to using actual data recorded in the Lake Geneva region. Lu et al [18] evaluated the capability of candidate relays to forward packets using 100 stationary nodes placed randomly in a 1km-by-1km square area. After training the SVM algorithm with the data, the relays for video streaming are selected for multihop communication. Huang et al. [23], proposed a model to add a learning design to cognitive radio engine based on Bit-Error-Rate (BER), SNR, data rate and modulation mode. Trained data for the SVM algorithm was based on 3 models: flat fading model, deep fading model, and no fading model. Zhang and Zhai [56] applied ML in Spectrum sensing using SVM to classify a new user asa primary user or not based on the received signal parameters: circulation prefix processing, carrier, repeatability extension and pulse sequence.

A few authors have compared SVM with other supervised learning algorithms like Artificial Neural Network (ANN) and have found SVM to have a better performance. In Sankhe, et al. [21], the paper used SVM and ANN methods to select the number of mobile users (relays) willing to engage in a cooperative communication after which the best relay was selected based on BER. The willingness is considered as a class label while the battery power, time of day, and incentive offered by service provider are used as features. An artificial dataset (with 50 inactive users assumed) was created to test the algorithm. The SVM outperformed the ANN algorithm with higher accuracy and less mean square error.

- ***K-Means Clustering***

K-means clustering is an unsupervised learning algorithm used for grouping objects based on similarity. Most of the studies on the application of k-means clustering in wireless communication has been in wireless sensor network, where the algorithm is modified to form cluster heads and the cluster heads act as relays that route traffic from the source node to the destination. One of the few researches on the application of k-means clustering in a device-tier 4G/5G network is the work of Hajjar et al. [33], where k-means was used to select the cluster heads for relaying, as in Figure 6. At the outer cell, the K-means is used to cluster cells based on their path-loss similarity. At the inner cell, selection strategy is used to maximize direct link association. To relay its message to the source, the unconnected user (slave) chooses one of the cluster heads, which now serves as a relay. Cluster head is chosen based on fixed parameters - distance and residual energy; however, these might not be the best parameters at all times for a dynamic network.

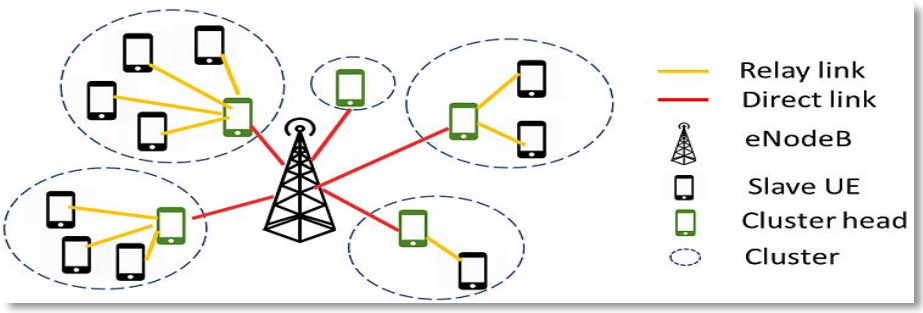

Figure 6: Multiple Relay Selction using K-means.

The k-means algorithm can be used for exploratory data mining and prior classification. In the latter, an unlabelled dataset is first grouped into clusters and labels are given to each cluster for further classification. A practical example of such work is in intrusion detection systems, where k-means clustering has been applied for training unlabelled data sets that contain normal and anomalous traffic. In Münz, et al [57], the authors assume that normal and anomalous traffic form different clusters in the feature space. They chose an initial cluster value of K=2, assuming that two clusters of normal and anomalous traffic are formed from the training data. By this, a new object can be classified based on its proximity to the centroid of the cluster groups. As shown in Figure 7, a new object *P* is closer to normal class than the anomalous class and is thereby classified as a normal

traffic. This is possible via the algorithm in Figure 8. The significance of this algorithm with other relay selection policies is very critical in 5G cooperative communication context.

Figure 7: Network traffic Classification for k = 2.

Rather than apply only k-means clustering, which will be tedious for labelling large data set, Yassin et al. [58], integrated a classification algorithm, Naïve Bayes Classifier, which is a supervised learning algorithm like the SVM. K-means clustering was applied to label the dataset, based on the behaviour, into two classes: normal or attack. This can be described as a type of hybrid algorithm which will be discussed in the next Section. Obviously, K-means clustering has proven effective for working on large dataset. Faraoun and Boukelif [59] applied k-means clustering to the training dataset to reduce the number of data samples to be applied in neural networks. Putting this in context, k-means can be used to pre-process network data in a large network for further application of classification algorithm. Sankhe et al. [21] proposed an algorithm to predict users willing to form a virtual MIMO based on SVM or ANN. The dataset consists of features like the user's battery power, time day and incentive amount and a class label for willingness. In a network with large dataset, the k-means clustering can be applied to reduce the amount of data required for the classification algorithm thereby further reducing the cooperative node discovery time. The issue is that K-means clustering cannot deal with categorical features, Jianliang et al. [60], like the day of the week. To deal with this, a unique ID can be assigned to each day. Figure 8 outlines the k-clustering design framework and its K-cluster algorithm used for relay selection in 5G Fog network (highlighted in Figure 9 and 10).

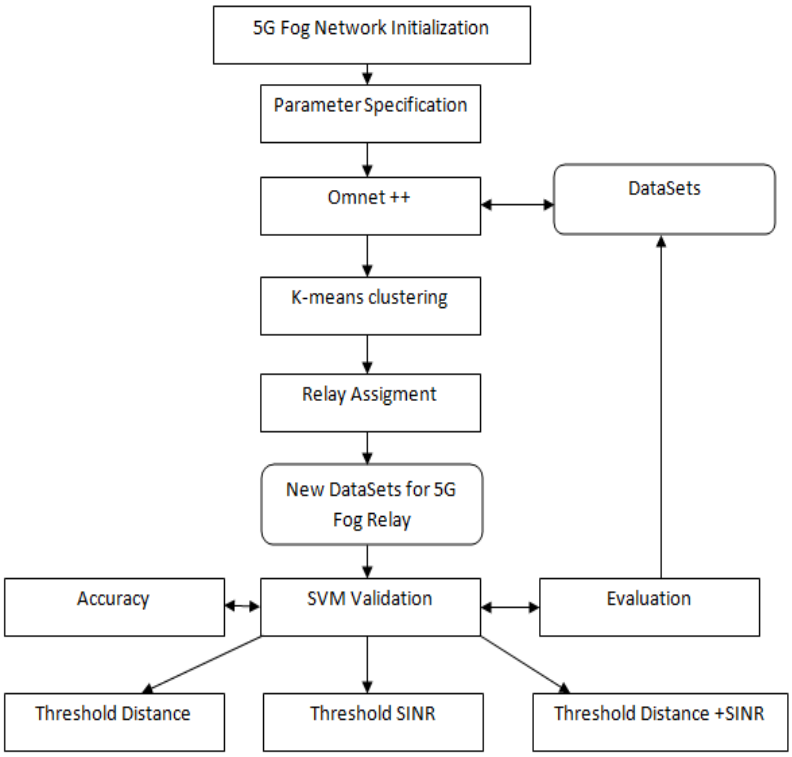

Figure 8: 5G Fog network k-clustering relay design.

Table 4. k-clustering relay algorithm for 5G Fog Relay Network

Input: $K, K_1, K_2 \ldots\ldots\ldots\ldots, K_i$
Output : , K_j, RMSM, Accuracy, Threshold-distance, threshold SINR and threshold-distance-SINR techniques, etc.
While True, **DO**
$K_i \leftarrow Null$
For $1 \leq i \leq n$ **DO**
$K_j \leftarrow SVM_{read}(Choose\ initial\ K\text{-}number\ of\ randomly\ placed\ centroid)$
$K_j \leftarrow Compute\ the\ Euclidean\ distance\ for\ each\ object\ to\ its\ centroid)$
$K_j \leftarrow Assign\ each\ object\ to\ the\ cloest\ centroid$
$K_j \leftarrow Adjust\ the\ centroid\ position$
Append (K_i);
end
$\tau = calculate\ and\ check\ for\ the\ centroid\ positional\ changes\ (True\ or\ False)$
Return
For $1 \leq i \leq n$ **DO**
$K_j \leftarrow QoS$ (RMSM, Accuracy, Threshold-distance, threshold SINR and threshold-distance-SINR techniques)
$SVM_{write}(Relay\ selection\ for\ data\ transmission)$
end
end

improve the efficiency of the single algorithm or to compensate for its deficiency. SVM has been combined with other algorithms to form a semi-supervised learning algorithm aimed at better performance. Yao et al.[61] proposed SVM algorithm based on k-means clustering (K-SVM) whereby the most informative samples are chosen by the clustering method. The authors argue that this method reduces the scale of training set and saves computation and classification time.

The final training data for SVM becomes the output of the clustering. In practice, the K-SVM has gained considerable popularity among researchers for applications like intrusion detection, Tran et al.[62] Shrivastava and Ahirwal [63]. Applying K-SVM in intrusion detection, Shrivastava and Ahirwal [63] argues that SVM is theoretically better than other classifiers because it requires a small number of classes during classification while K-means reduces the training time by filtering the less useful data points. When compared to Navie Bayes, the K-SVM algorithm showed a better performance with 99% accuracy compared to the former's 80.5%. The limitation of this method is that the dataset should have pre-assigned labels. Considering that the 5G network is very dynamic with variable network and condition and user requirement, it might not be realistic to train the algorithm based on a fixed number of features. In such a case, an algorithm that can learn the peculiarity of the users in the network independent of the network condition is required. One of such well-known algorithms is k-means clustering. Table 5 summarizes the application of the machine learning algorithms in several literature relating to CC with the source of data, algorithm tools, and evaluation criteria.

Table 3. ML Algorithms and Application Areas in CC.

Application	**ML Algorithm**	**Parameter**	**Data source**	**Evaluation**	**Reference**
				Tool used	
Virtual MIMO Formation	SVM & ANN	Class label: willingness (yes/no?) Features: battery	Artificial dataset	Accuracy: 97.70% (ANN) 97.92% (SVM)	Sankhe et al. [21]

		power, time of day, incentive offered by service provider		'LIBSVM' library (SVM); Encog library (ANN)	
Best Relay Prediction	ANN	Input: The average link qualities and number of relays and the	Artificial / Modelling 12500 samples for training and 3125 samples for testing	2dB less power usage	(Kara et al. [42].
Optimal Base Station Prediction	Recurrent Neural Network (RNN)	Received signal strength (RSS) values	Artificial - Assumes a 6km x 6km road network	Accuracy: 98% Google's Pythonbased Tensorflow library	(Wickramasuriya et al. [54].
Next Cell Prediction	Support Vector Machines (SVMs)	Features: User's position, residence time inside the cell, ID of the cell	Actual data recorded in the Lake Geneva region	Accuracy: ~80% RapidMiner Data Mining framework	Michaelis, et al [55].
Relay Selection For Video Streaming	SVM	Features: Source transmission count (ETX)	Simulation data: 100 stationary node placed randomly in a 1km-by-1km square area.	Outperforms baseline approach	Lu, et al. [18]
Adding Learning Design to Cognitive Radio	SVM	Class label: Modulation Features: used for testing: BER, SNR and data rate	Actual dataset: 69446 training samples and 34723 testing samples	Accuracy: >99%	Huang et al. [23]
Spectrum Sensing	SVM	Class label: primary user (yes/no) Features: circulation prefix processing, carrier, repeatability extension, pulse sequence	Artificial: 1600 training samples, 1000 testing samples	Better recognition than energy detection	Zhang and Zhai [56].

3. Proposed Relay Selection Network

3.1. Fog-Data offloading

Figure 9 illustrates our distributed data processing in a scalable Fog-computing environment [64]. The system requires k-means clustering. Based on the functionality the cooperative communication system, users can deploy IoT devices at the edge layer which is then connected via a relay cluster to the cloud. Once the system collects information from the sensors, the Fog layer will balance with nearby gateways and private clouds. This dynamically conduct data analytics and facilitate the network scalability for bandwidth intensive contents. Data offloading is bridged using Fog relay nodes based on k-means clustering. At the edge, the component for data-processing or analytics applications offloads data in scalable distributed cloud via the Fog gateways. The Fog layer facilitates the management and programming of low latency computing, networking, and storage services

between cloud provider datacenters and end devices. In addition, it supports user mobility, resource and interface heterogeneity, and distributed data analytics to address the requirements of widely distributed applications that need low latency. In this case, the k-means clustering combines with relay selection polices such as max- link selection [65], Successive opportunistic relaying (SOR), [66], [67], and opportunistic relaying [68]. This is particularly useful in Figure 9 since, the Fog relay arrays places lighter-weight on the IP cloud by defaulting proximity of edge mobile devices. Hence, it offers load-balancing between the thin-clients and the IP cloud considering its localized sites for location-aware services commonly found at the end-users domain.

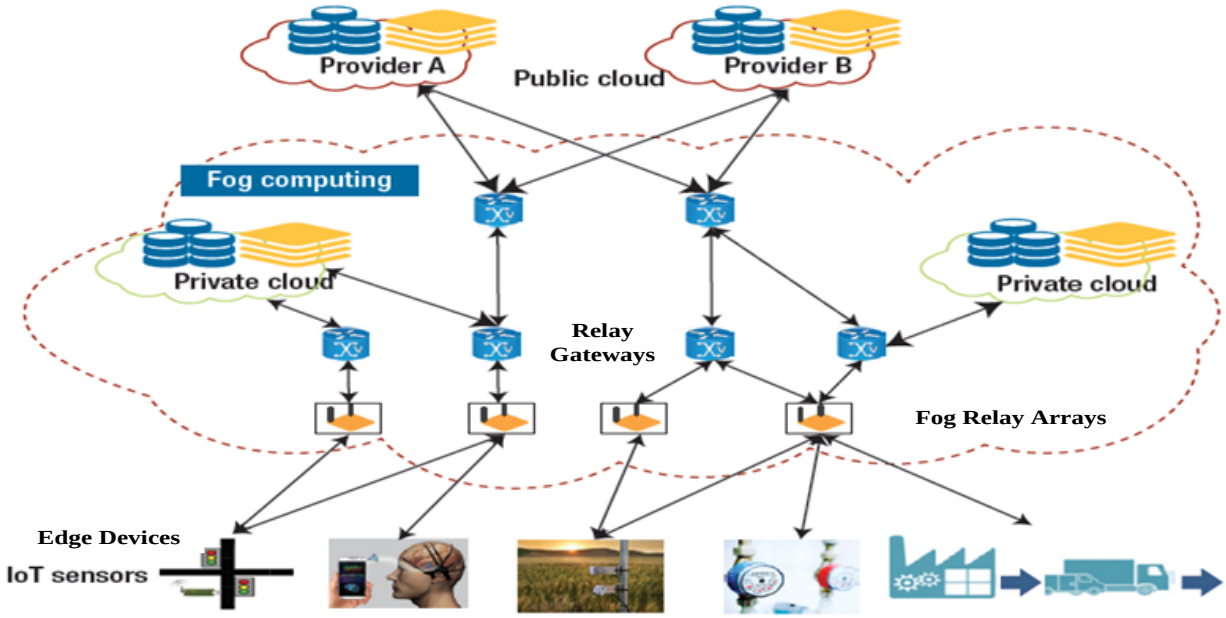

Figure 9: Proposed 5G Fog network Architecture

Figure 10 shows a classical topology with riverbed modeler for wireless Fog communication. In this case, the source and destination nodes are interconnected by means relay arrays in clusters. The network edge devices as (sources) and destination gateways communicate to each other directly since the distance between the source and destination is lower than the transmission range both end points. The Fog relay arrays are used to send sensed events between two devices, especially when distance is a consideration like in 5G domain. In Section 4, a two-tier 5G cellular network is designed for i) a densely-populated area, ii) moderately populated area and iii) the least populated area. The system model used in this work consists of the eNodeB and the UEs (STAs) similar to Figure 6. The eNodeB serves as the base station and resource allocator. It is assumed that UEs can communicate via two modes, namely cellular mode or cellular-D2D mode. In the cellular mode, the user establishes uplink and downlink communication with the base station. In the cellular-D2D mode, the user can either participate in a cellular communication or a D2D communication. When the user is in cellular-D2D mode, it is assumed that the user is capable of both modes of communication but at different time slots. In the network, any of the mobile UEs is a potential candidate for relaying, depending on the network conditions. The experimental discussions are presented in Section 4. Let's look at the typical performance metrics for 5G Fog model.

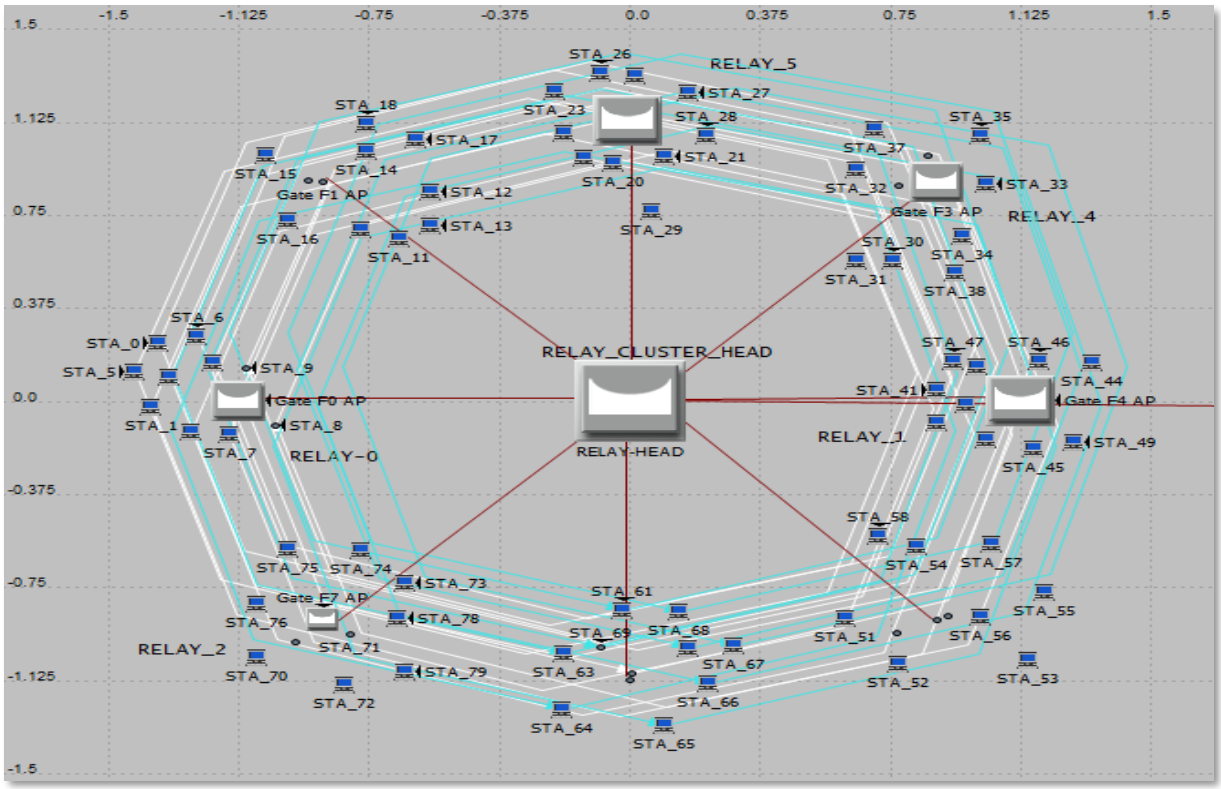

Figure 10: Fog-relays for distributed processing in 5G Senario.

3.2. Performance Evaluation Metrics

In the 5G Fog model, performance of proposed K-means with SVM as well as other selection policies (previously highlighted) is analyzed using the following metrics:

- Accuracy: This is the 5G model metric that accesses how effective the algorithm identifies the true value of the class label and is given by Equ. 1.

  $$\text{Accuracy} = \frac{\text{tp}+\text{tn}}{\text{tp}+\text{tn}+\text{fp}+\text{fn}} \quad (1)$$

  Where tp is the number of true positives (the number of times a user is correctly classified as a relay); tn is the number of true negatives (the number of times a user is correctly classified as a non-relay); fp is the number of false positives (the number of times a user is incorrectly classified as a relay); fn is the number of false negatives (the number of times a user is incorrectly classified as a non-relay).

- Root Mean Squared Error (RMSE): This is 5G Fog model error metric used for numeric predictions, hence serving as accuracy measure in the network.

  $$\text{RMSE} = \sqrt{\frac{\sum_{i=1}^{n}(p_i - a_i)^2}{N}} \quad (2)$$

  Where a is the actual observed values and p is the forecast values.

In this work, the k-means algorithm is evaluated against other existing relay selection techniques such as the threshold-distance algorithm and threshold-SINR algorithm discussed in Section V. Now let's look at the Threshold-based techniques for relay selection. For the purpose of evaluating the performance of the proposed algorithm, the threshold-distance, threshold SINR and threshold-distance-SINR techniques used for relay selection are highlighted below.

- Threshold SINR

In [17], a threshold based relay selection is described where a set of relays, called "reliable relays", is chosen to forward a received message only if the received SNR exceeds a threshold value. When SINR is used as a measure of link quality, the reliable relays are relays whose source-relay SINR are higher than a given threshold. They have a lower probability of error and can retransmit the source signal. One of the reliable relays can then be selected based on the relay-destination SINR. Assuming a time slotted system where the source broadcasts a signal with a given signal power, the ith relay node is said to be reliable and can correctly decode the source data when:

$$\mathrm{SINR_{ri}} \geq \mathrm{SINR_{target}} \quad (3)$$

Where $SINR_{ri}$ is the received SINR and $SINR_{target}$ is the threshold SINR. For evaluation, the SINR centroid obtained from the K-means clustering is assumed as the threshold SINR.

- Threshold Distance

In this case, the relay capability is assigned to UEs whose distances are above a given threshold. Assuming a uniform distribution of relays, the cooperative relays can be selected from candidate relays located within a radius of fixed proportion (threshold) between transmitter and receiver. For evaluation, the threshold is defined by the distance centroid obtained by the K-means clustering.

- Threshold distance and SINR

The combination of distance and SNR metrics is introduced for relay selection based on the high reliable relay selection algorithm [69]. The reliable relays are those UEs which have a higher SNR than others and reside
within the threshold distance D_{th}. These are used in the experimental analysis of the propsoed 5G Fog model.

4. Experimental Results and Discussions

In this Section, the experimental evaluation in Omnet++ simulation [70], [71], [72] is presented. In context, the performance of a two-hop relay transmission scheme is discussed similar to the work [75]. The system considered a best relay selection strategy regardless of any direct link between the communicating devices in the edge Fog scenario. OMNeT++ is C++-based discrete event simulator used for modeling Figure 9 while using tuning parameters in [75]. This DES comprises modular, component-based C++ simulation library used for building a synthesizable network as well as carrying out empirical evaluations. Monte Carlo simulation concept was enabled to run with average data values which was plotted in Figure 10 and 11. For the CC 5G network environment, the relays are assigned to each cluster dynamic by default and hence can change anytime. The performance of the proposed relay selection scheme is done to demonstrate the effectiveness of relay selection strategy as detained in [12].

As shown in Figure 11, the accuracy of the proposed relay selection technique has better performance compared to threshold-SINR, threshold-distance and the threshold SINR-distance techniques for all the different numbers of UEs. An error metric called Root Mean Squared Error (RMSE) is shown in Figure 12. The proposed technique has lowest error relative to other techniques. The proposed algorithm also improves with larger dataset unlike the threshold based algorithms that do not show any significant improvement with increased dataset. The k-means clustering significantly segmented the netwok data into groups based on the similarity between the data. In this case, the Fog cluster contains data points with similar attributes. The similarity between data points is measured by the Euclidean distance. The performance of the established algorithm is affected by the initial selection of centroids and the value of K. The process is iterative in that it continues until there is an insignificant change in the sum of squared distances between the points and the centroid.

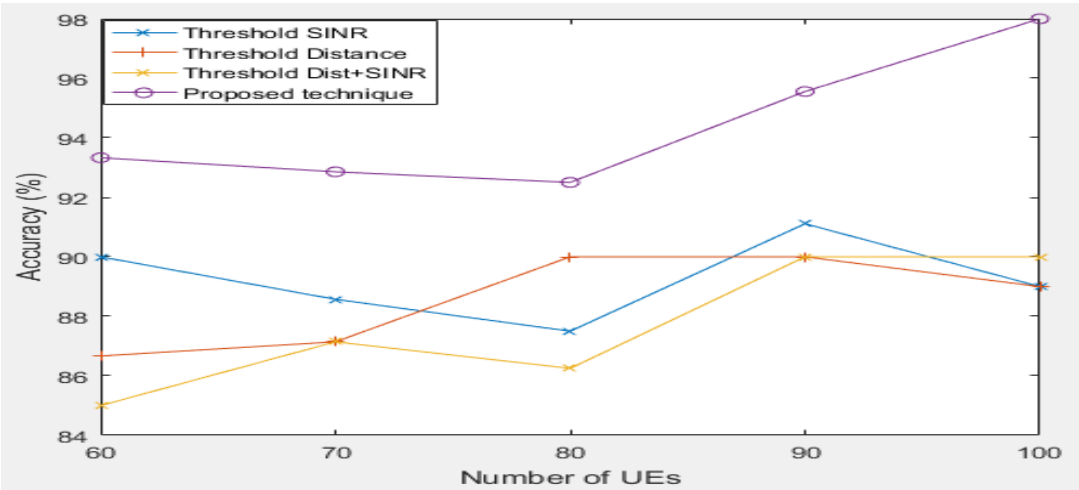

Figure 10: Accuracy metric comparision in 5G Fog-relay.

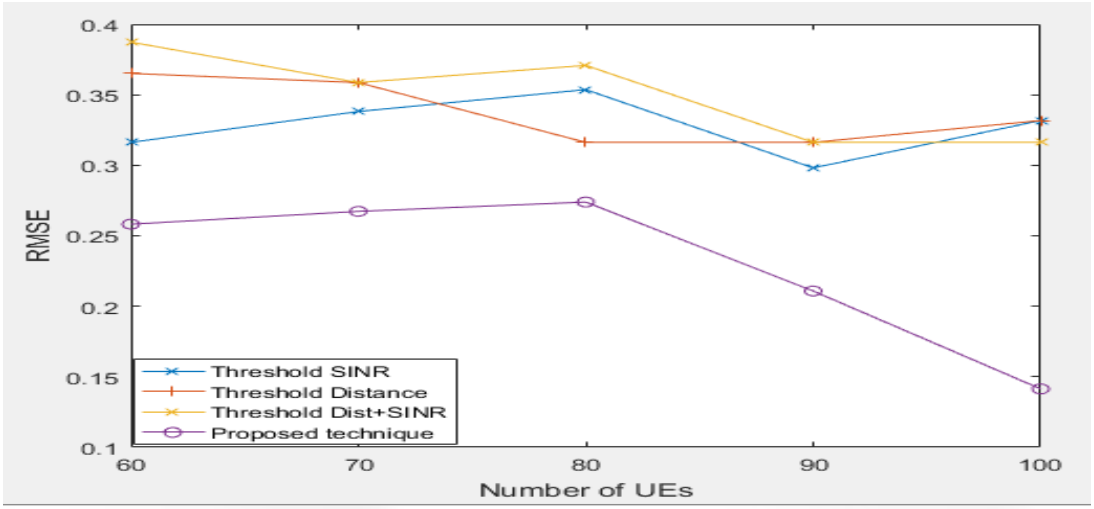

Figure 11: RMSE metric comparision in 5G Fog-relay.

For the three scenarios, the proposed technique offered better performance in terms of accuracy in terms of datastreams fordwarding. Clearly, the 5G Fog network cannot survive traffic demand as data offloading requires satisfactory QoS parameters based on user demands and network situation. So far, this work has shown the apparent need to design an efficient relay selection model for 5G-Fog networks. Based on the performance requirement of the network and its expected usage and data rate demand, the mobile industry needs to save cost, and time required in cooperative communication. This work provides a good ground for further research in the utilization of machine learning algorithms for 5G network applications where improvement can be made to existing algorithms and protocols.

5.Conclusion

In this paper, attention was given to an efficient relay selection in Multihop D2D communication on a 5G Fog distributed platform. A two-phase transmission with a set of reliable Fog relay arrays are selected for the phase -1. Using dataset simulated in Omnet++ environment, a natural grouping of mobile users was discovered based on relay capability. The “reliable relays” were identified thus reducing the number of relay nodes for the second transmission phases. In this case, an intelligent and dynamic relay selection using k-means clustering was proposed for further communication. The best relay selection, improves the QoS. Furthermore, to show the efficiency of the proposed scheme, Monte Carlo simulation analysis was employed to ascertain the success of the appropriate relay selection for QoS. By using the K-clustering optimization algorithm, we identified the parameters for

relay selection strategy. Future work will focus on different scenarios for 5G Fog relays while generating appropriate datasets for algorithm validation using parameters such as SNR, data rate, latency, throughput, energy efficiency, and reliability. The use of SVM algorithm as a validation tool to evaluate the accuracy of the proposed design against these techniques. Also, Feed Forward Error-Back Propagation Neural Network [73] will be compared with SVM using Best Channel Quality Indicator Best-CQI), Round Robin and proportional fair techniques [74],[75]. A contextual cyberphyscial application for 5G fog relay will be presented in a future research.

7. Acknowlegements

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