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Cooperative Communications in Machine to Machine (M2M): Solutions, Challenges and Future Work

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ABSTRACT The application of cooperative communication (CC) in wireless networks makes it possible for the terminals to hear and aid the transfer of each other's information to the required destinations. CC utilizes the advantage of the broadcast nature of wireless communications to achieve its objectives. The advantages enjoyed by networks that employ the principles of CC include: improvement of connectivity, improvement in energy utilization, spectrum efficiency, counteracting of the limited per device complexity, and a boost in communication reliability among devices in the network. When CC is compared with other techniques that perform functions similar to it like multiple input multiple output, it has an upper hand due to the fact that CC has a hardware that is feasible and its deployment is more flexible. The implementation of CC in machine to machine (M2M) in this paper is based on the use of relays and clustering protocols. Popular protocols of relays and clustering are presented as solutions, and detailed emerging research challenges that include but are not limited to: escalating complex scheduling design, increased message overheads, increased intra and inter network interferences, increased end-to-end latency, and redundancy are discussed. Future works that includes critical application of full duplex relays, utilization of non-regenerative mode of relay operation, cross layer optimization, application of clustering scheme with reconciling quality-of-service properties, and designing of hybrid clustering techniques are proposed. They are aimed at improving on the challenges and hence foster efficiency in M2M network resources.

INDEX TERMS Clusters, cooperative communication, M2M, relays, WSNs.

I. INTRODUCTION

CC initiated through the use of relays and clustering protocols are presented as solutions through which terminals in the communication networks are able to solve the problems that affect the efficient operation of M2M communications networks. In the recent development, cooperative schemes have been well adopted for 5G wireless systems with the main goal of ensuring efficient use of limited resources [1]. Efficient use of the network resources brings about reliability and significant error rate reduction. However, such a rapid shift in communication results in wastage of the total limited power without providing precise reduction in performance requirements such as network lifetime. Currently, the demand for the network access has continued to rise due to the sporadic rise in the number of M2M devices [2].

The network operators are working round the clock trying to keep pace with the high demand of the wireless network and keep the required QoS. This has placed them at the top of the list in terms of energy consumption. The high usage of energy resources has made majority of researchers to focus their work towards the provision of solutions that increase energy efficiency in the networks [3].

The component, the link and the system levels of the access network have been focused on in wireless network with the main aim of addressing energy efficiency [4]. Further fact-finding is being directed towards working on the wireless technologies, network protocols and architectures [5]. The target is to have efficient utilisation of energy resource in the network. There is need to pay more attention to network architecture to provide solutions to the problems that exist in the wireless access network. However, this has not been the case. Much focus has been directed to mitigating interference, raising spectral efficiency and extending the network coverage in the network architecture and deployment [2].

The 5G network architecture scenario involves the application of strategies that minimise energy consumption. This is investigated in [1]. Abuali [2] when discussing how to achieve energy efficiency in wireless communication network, they advocated for cell size optimisation. The introduction of cognitive radio and adding heterogeneous networks that are broken down as overlaying macrocells with femto, Pico and microcells. Further discussion included locating non-cooperative and cooperative relay nodes in the network architecture. Among all network architecture techniques, cooperative communication approach has received special attention in recent literature.

Cooperative communication schemes are yet to perform to their expected potential. There are still crucial challenges that emanate from the energy management approach in the network that need urgent attention. From literature, various proposals have been put forward. When cooperative communications technology is applied in M2M network it posts positive results that includes but is not limited to; increase in network operation period, reduction in network interferences and expansion in coverage. The device to device (D2D) communications discussed in [6] is a good example of CC and enjoys the same advantages. The application of cooperative technology in M2M network looks promising. However, there are still holes that need to be examined to find lasting solutions. Some of the open questions presented that call for answers include: when and how to apply cooperative communication in the network for optimal results and channel modeling [7].

Low power M2M networks have two main challenges that affect their effective operations: the processing complexity and transmission range constraints. The two challenges are addressed through cooperative communication. CC sets appropriate platform for the prolonged operation of the low power M2M networks. Many wireless devices that might also be present in M2M networks are smaller in size and are less complicated in their design. Hence, the introduction of cooperative approach in the network serves to eliminate complexity limitations of the devices enabling them to perform more powerful system-wide complex tasks [8]. The long distance towards gateways or base transceiver stations covered by some M2M devices in the networks results in higher power consumption per link. Cooperative communications examined in [9] and [10] provide a solution to long distance transmissions that involves the utilisation of multiple short hops. Cooperative communications have diverse applications in networks; they include increasing capacity or coverage extension, transmission reliability, network throughput and network stability.

As identified in recent literature, Cluster Based Routing Protocol (CBR) [10], [11] is presented as one of the solutions to the many existing energy challenges in WSN. Further observations are captured in [12], where CBR is applied in mobile sensor nodes in WSN in which it is referred to as Cluster Based Routing Protocol for Mobile nodes in Wireless Sensor Networks (CBR-MWSN). CBR and CBR-MWSN protocols which incorporate node scheduling in their operation using Time Division Multiplexing Access (TDMA) [11] are the relevant mobility centric protocols that find their application in M2M communication networks. The utilisation of TDMA fails CBR and CBR-MWSN protocols as it is not energy efficient. Use of clustering and relaying approaches suffer from: (i) higher energy consumption by the cluster heads than members of the cluster. (ii) The likelihood of each device being appointed as a coordinator requires that each Machine Type Communication (MTC) is designed with double transceivers [13]. This type of design arrangement makes the whole set up overpriced.

The initiating of gateways as relays is examined in [14]. It plays a cooperative role of collecting and processing data from the neighbouring devices within the network. In this arrangement, the gateway plays the role of the cluster head. The major advantage of the gateway is its ability to operate for quite long as it does not have energy limitations. Further benefits of gateways stems from the fact that they own no data that needs to be transmitted to the Base Transceiver Station (BTS), it does not introduce any congestion but only acts as a link in the network. The major contribution of the gateways in the network is energy efficiency. It helps to maintain stability in the operation of the M2M networks as it consumes no power. A good performance from the M2M gateway is experienced when half duplex is utilised in the design; it counters self-interference and presents no hard challenge during the implementation stage [15]. The need to cover a wider network is reviewed in [16], the authors suggested the addition of MTC gateways in the cellular network to address the massive access requests. Further solution to the high number of access requests is taken up by incorporating the network capillary networking [17] which is a cooperative approach.

Figure 1 portrays a cooperative M2M communication network [18]. Basically, it is described as being made up of M2M area and core networks. The numerous number of sensor nodes that make up M2M area network are connected to the core networks through gateway nodes. The M2M communication network presented in Figure 1 is performing the function of health monitoring, traffic controlling and monitoring, home security and agriculture. As described in [19], the M2M devices are linked to the network domain via an M2M gateway, while the M2M devices are linked to the M2M gateway using the M2M area network. The description of M2M gateway is investigated in [20]. The gateway is worth being mentioned in the presentation as acts as a substitute for the network domain to which the M2M devices are connected. The connectivity between M2M devices and M2M gateways is accomplished through the M2M area network. Examples of M2M area networks include Personal Area Network (PAN) technologies such as IEEE 802.15.1, ZigBee and Bluetooth.

The application of relays in connecting devices, use of gateways in accessing the core network and clustering approach on M2M access area are depicted in figure 1. Some of the far-reaching challenges of cooperative

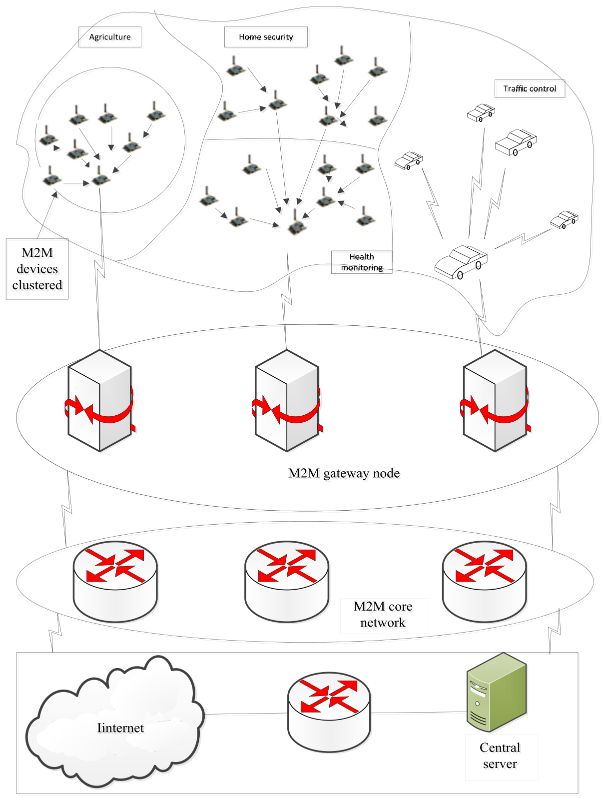

FIGURE 1. Cooperative M2M communication network [21].

communication in M2M networks include increased end-to-end latency, complex scheduling, increased overhead and the problem of uneven distribution of M2M devices in the network makes the clustering process difficult if not impossible. In the recent years, large amount of work has been published in cooperative communications. However, most of it has been biased towards the WSNs. In summary, the main objectives of this survey can be listed as: (1) To explain and make readers aware of the best relays and clustering protocols that can be investigated for cooperative communication in M2M; (2) To highlight some of the challenges in regard to the use of relays and clustering protocols; (3) To describe the various approaches of relays and clustering protocols to application designers and then assist them to select the most appropriate technique to be used. In this review paper, cooperative communication is divided into two groups; the use of Relays and Clustering protocols. This paper explains how cooperative communications through the use of relays and clustering protocols that is utilised in WSNs is extended to M2M. This work is unique in the following ways: (1) To the best of our knowledge, this survey is the first to present the use of the most popular relays and clustering protocols as solutions to cooperative communication in M2M; (2) It discusses some of the challenges on the use popular relays and clustering protocols. To the best of our understanding the most comprehensive approach as it gives direction on which approach can be utilised with good results; (3) it presents some suggestions for future work with the aim of improving on performance when popular relays and clustering protocols are examined for M2M.

This paper provides existing solutions, emerging challenges and future work for cooperative communications in M2M networks.

This paper is organised as follows: Part I describes an overview of CC, Part II introduces relays, Part II: I. discusses the types of fixed relay techniques. Part II: II. Presents the types of adaptive relays techniques, Part II: III, presents the challenges in the use of relays and Part II: IV. Discusses future work in the use of relays. Part III introduces clusters, Part III: I. presents centralised clustering protocols. Part III: II discusses decentralised clustering protocols while Part III: III presents challenges in the use of clusters. Part III: IV discusses future work in the use of cluster and Part V presents the conclusion. For convenience purposes and to make it easy for the readers of this review paper, the following is the list of abbreviations mostly referred to and their definitions.

CC	Cooperative Communications
AF	Amplify and Forward
CF	Compress and Forward
CH	Cluster Head
DEEP	Distributed Energy Efficiency Protocol
DF	Decode and Forward
D2D	Device to Device
EEHC	Energy Efficient Hierarchical Clustering
H2H	Human to Human
HEED	Hybrid Energy Efficient Distributed
IR	Incremental Relaying
LEACH	Low Energy Adaptive Clustering Hierarchy
M2M	Machine to Machine
MTC	Machine Type Communication
SDFR	Selective Decode and Forward Relay
UE	User Equipment
VANETS	Vehicular Networks

PART I: OVER VIEW ON COOPERATIVE COMMUNICATIONS

This subsection presents an overview on operation of CC, the relay architectures and two major divisions of CC.

PART I: I. OPERATION OF COOPERATIVE COMMUNICATION

Cooperative communications came into operation after first article that discussed relay channels [22]. The article described a relay channel as being made up of the source, relay and destination nodes. Nevertheless, cooperative communications is much more than the relay channel concept that operates as described in [23] as follows: in the first phase, source node sends (broadcasts) data to its destination and the same data is also received by the relay node due to broadcast. In the second phase, the relay may help the source node by forwarding or retransmitting the data to the destination, the destination receives data from two sources. In cooperative

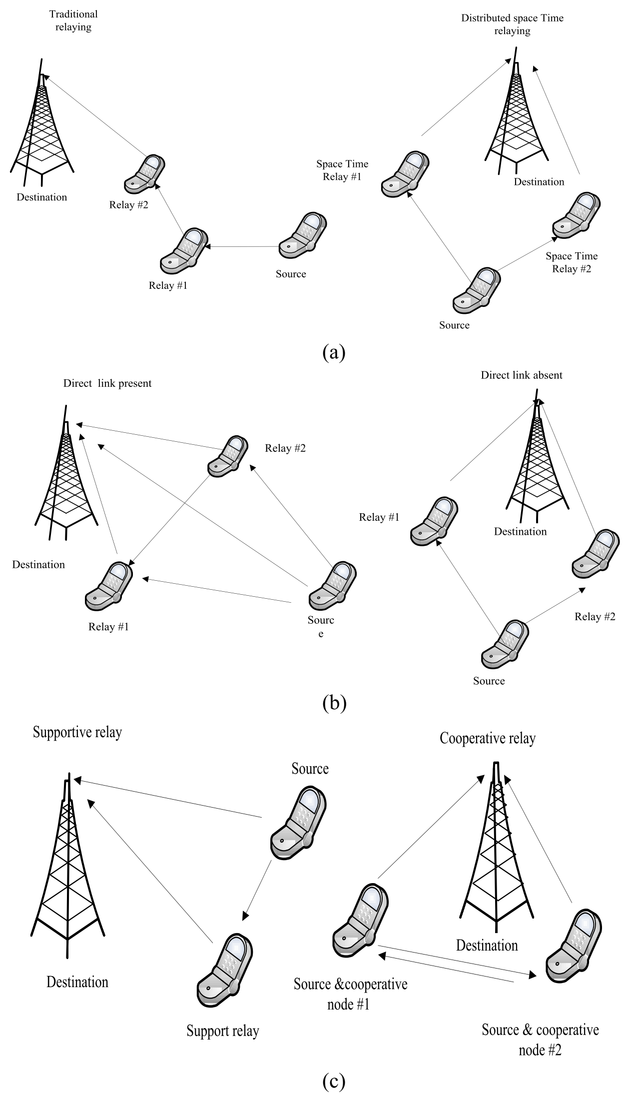

FIGURE 2. **(a) Traditional relaying and distributed space time relaying [23]. (b) direct link available for source and no direct link for the source to destination [23]. (c) Supportive relaying and Cooperative relaying [23].**

communications, users are sources of information and also play the role relays. In the discussion of relay channel, TDMA and FDMA are the channel access technologies that are used to model the relaying scheme [24]. While TDMA is a digital technique that divides a single channel or band into time slots, FDMA divides the shared medium bandwidth into individual channels. They are designed to operate in such a way that interference between any two phases is eliminated.

PART I: II. COOPERATIVE RELAYING ARCHITECTURES

As presented in [25] the canonical relay architectures describe relaying either as traditional relaying or distributed space time relaying, availability of direct link or absence of direct link and supportive or cooperative relaying. The illustrations of the above mentioned architectures are presented in figure 2. Figure 2 (a) presents the cooperative architectures of the traditional relaying where the signal from the source reaches the required destination through multi-hop communication. Distributed space time relaying is where two or more relays receive information from a common source, they process and forward them to the destinations. Thus, this form of arrangement of distributed processing of signal at the different relay nodes creates a virtual antenna array. This is equivalent to describing the two types of cooperative transmissions; direct and cooperative transmissions

Figure 2(b) describes the cooperative architecture where the source can access the destination either through the utilization of relay links through other nodes along its route or directly.

Figure 2 (c) demonstrates the supportive and cooperative relaying architectures respectively. The source forwards the signal to the destination directly as well as through another relay in support relaying. While on the other hand cooperative relaying is where the relays are sources of the signals and also perform the function of forwarding signals from other nodes. In this two cases they help to improve multiplexing gains as well as diversity of signals delivered to the destinations.

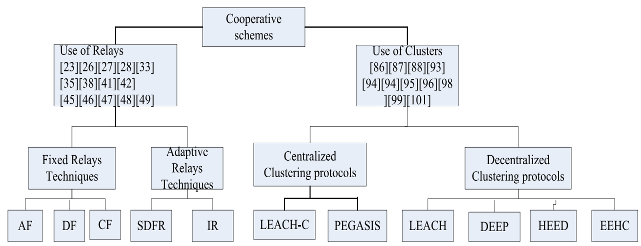

FIGURE 3. **Two major divisions of cooperative communications (Use of Relays and Use of Clusters).**

PART I: III. DIVISIONS OF CC

CC is classified into two major divisions; the use of relays and clusters divisions as illustrated in figure 3. Each division is further sub-divided into two with popular examples in each

This section highlights the fundamental relaying protocols that are applied in cooperative relaying. They are classified into two main groups; fixed and adaptive protocols.

PART II: I. FIXED RELAYING (FR) TECHNIQUE

Fixed relaying is where there is a fixed division of the channel resources between the source and the relay. In fixed relaying, users not only broadcast their own message but through cooperation they also relay some data on behalf of each other to the destination [23]. The process employed by the relay to send data from the point of origin to the destination or end is also referred to as protocol. The protocols under FR are listed as; Amplify-and-Forward (AF), Decode-and-Forward (DF), Compress-and-Forward (CF) and Coded Cooperation (CC) [26]. However, in the studied literature, AF and DF have been addressed more times due to their wide applications in networks as compared to other cooperative relaying schemes.

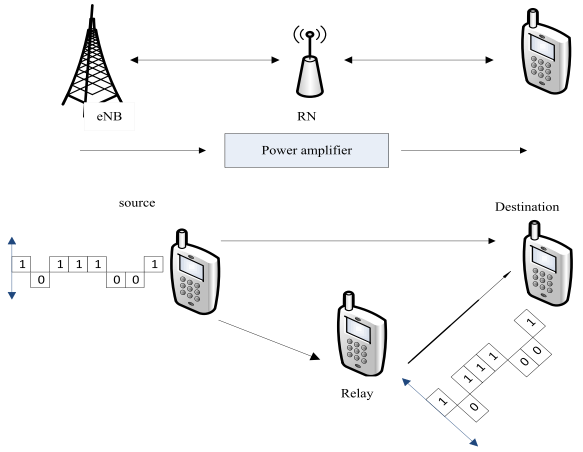

FIGURE 4. Amplify and Forward protocol [28].

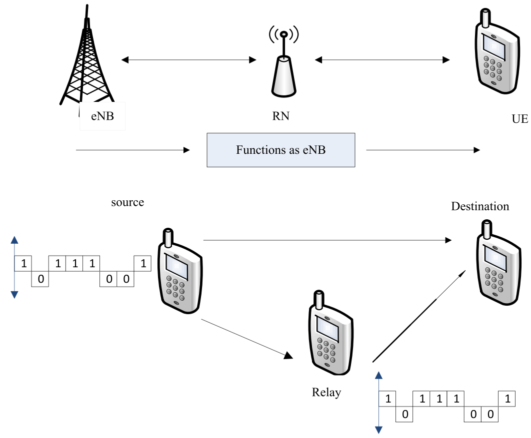

FIGURE 5. Decode-and-Forward Protocol [35].

A. AMPLIFY AND FORWARD (AF) PROTOCOL

In the AF convention, the relay scales the received data and then amplifies what has been received before forwarding to the destination end [27]. The power requirement in AF is little since no decoding or quantizing operation is performed at the relay side. The AF protocol is illustrated in Figure 4 [28]. AF is designed in such a way that the destination is able to receive the same message from the relay and from the original source of information or from a different relay, when there is direct transmission from the source to the destination [29]. The description fits the simplest form of cooperative protocol.

The modelling of amplify and forward relay channel can be performed as presented in equation (2). The destination and the relay receives a signal transmitted from the source X, this is defined as:

$$\begin{aligned} Y_{sr} &= \sqrt{Ph_{sr}x + n_{sr}}, \quad \textit{from source to relay} \\ Y_{sd} &= \sqrt{Ph_{sr}x + n_{sd}}, \quad \textit{from source to destination}. \end{aligned} \tag{1}$$

Here, the notations h_{sr} and h_{sd} represent the fading of the channel that links the source, relay and destination, respectively. n_r and n_{sd} represent the additive white Gaussian noise with zero mean variance N_0. By amplifying the source signal and forwarding it to the destination, the effect of channel fading is eliminated. In AF the received signal is scaled by the relay by a factor that is proportional to the received power, which is represented as:

$$\Psi = \frac{\sqrt{P}}{\sqrt{P|h_{sr}| + N_0}}. \tag{2}$$

The operation requirement that is based on the availability of Channel State Information (CSI) divides AF protocols into two groups: Variable Gain Amplify and Forward (VGAF) and Fixed Gain Amplify and Forward (FGAF). The need to maintain a fixed transmit power at all times by the VGAF relaying scheme needs a prompt CSI of the source-relay link at the coinciding relay. CSI is not a requirement for FGAF relaying scheme. The only factor to be considered is the average signal-to-noise ratio of the source-relay link. This plays the role of ensuring that fixed average transmit power at each relay is maintained constant [30].The destination receives data directly from the source as well as amplified data from the relay. AF relays are simple in design and are able to provide longer battery life than DF relay protocol. A further advantage involves their ability to recover the throughput loss that results from the extension of network coverage [31].

B. DECODE AND FORWARD (DF) PROTOCOL

DF protocol is the relaying scheme that decodes the source message and then re-encodes the data and retransmits it to the destination [32], [33]. The characteristic of this relaying scheme is that it transmits an amplified received signal to the fusion centre in its last time slot. The achievable rate of DF is described as max min, this can be presented in an equation form as: max min$(I(x_1; y_1|x_2), I(x_1, x_2; y_2))$ The simplest form of DF is as presented in Figure 5 [34], [35]. From figure 3, the received signal at the destination is given as:

$$\begin{aligned} Y_{sd} &= \sqrt{Ph_{sd}x + n_{sd}} \\ Y_{rd} &= \sqrt{\Psi h_{rd}x + n_{rd}} \end{aligned} \tag{3}$$

The advantage that DF has over AF is that it has a higher transmission performance index. However, AF enjoys the advantage of being simple in design. But for better performance it's worthy to consider both AF and DF in designing the final relay to be utilised in cooperative communications. Thus, the application of hybrid scheme which is examined in [36], it is a better option as it addresses the shortfalls of both AF and DF protocols.

C. COMPRESS AND FORWARD PROTOCOL

DF operation is quite different from AF; in CF the signal is quantized and then compressed before retransmission to the destination. CF is applied when it is not possible for the message from the source to be decoded. Thus, the receiver node at the destination receives and combines the message from the source node and the one that is quantized and compressed from the relay node [23].

During the operation of CF, the received signal is mapped onto another signal in the signal space that is reduced. This is followed by encoding and forwarding the compressed signal that is presented as a new code word. The performance of the protocols varies when compared in terms of the capacity of the system or diversity. All these will depend on topology of the network and the backhaul link quality that exists between the source and the relay node. The operation performance of the protocols have higher performance in a given backhaul quality link. DF performs better in systems whose backhaul links is good, while AF or CF based schemes perform well in systems whose backhaul links are poor [37]. The planning of the protocols in the network is important as it has bearing to their performance. For magnificent performance, DF should be positioned close to the source and CF closer to the destination. DF and CF with proper consideration of the backhaul link quality and proper positioning can yield optimal performance in the cooperative communication networks. Their major setback is the baseband operation that is complicated and drains the energy source of the network [38]–[40].

In [39] the discussion of adaptive relaying (AR) protocol is presented. AR offers solutions to the existing shortcomings of AF and DF protocols that include; rate reduction caused by allocation of half of the channel to transmission purposes. The spectral efficiency is lowered which is a big disadvantage to the communication network. Adaptive relaying protocols is divided into two main forms; namely Selective DF Relaying (SDFR) and Incremental Relaying (IR) [23], [41], [42].

PART II: II. ADAPTIVE RELAYING PROTOCOLS

Adaptive relaying protocols are basically divided into two groups namely, Selective Decode and Forward Relaying (SDFR) and Incremental Relaying (IR). Whereas SDFR bases its operation on the state of the channel that exists between the terminals that are cooperating, IR relies on the destination terminal limited feedback for its operation. The two protocols posts spectral efficiency in the network [43], [44].

A. SELECTIVE DF RELAYING (SDFR) PROTOCOL

SDFR performs the function of forwarding the received signal to the destination based on the principle that the signal to noise ratio of the signal received is above the required threshold. It is further observed that the relay remains idle if the condition of the channel that exists between the source and the relay is suffering from severe fading [45], [46]. The operation of this relay has a lot of advantages when it is compared with DF. While DF forwards to the destination all the decoded signals both correct and incorrect, SDFR is quite selective and hence it comes in as a solution to the problems that exist in DF [47]. The protocol tries to save the spectrum by restricting the relaying process only to the necessary conditions [42].

TABLE 1. Advantages and disadvantages of Fixed and Adaptive relays.

Fixed Relaying		
Relay type	***Advantages***	***Disadvantages***
AF [26][27] [28]] [31]	Simple in design, Low cost implementation and less delay. Provides longer battery life than CF and DF, can recover throughput loss.	The noise and the interference are amplified. It is an "analog" cooperation schemes and this makes it difficult to be developed in systems that utilise TDMA technology in their operations. Sophisticated media access control layer is required.
DF [26][49][33][35]	Less time delay, consumes less power, Higher achievable rate when closer to the source	High processing delay and complexity, energy inefficient as it involves baseband operation. Suffers from error propagation problem.
CF [23][37]	Has higher achievable rate that is obtained when the relay is near the destination.	It involves baseband operation; hence it consumes more energy, its analog cooperation scheme.
Adaptive Relaying		
SDFR [38] [45][46]][47]	Avoids error propagation. Has high spectrum efficiency.	Expensive in terms of monetary expenses involved during its development.
IR [42]][48]	Offers best spectral efficiency, maximum possible diversity order can be achieved.	Expensive in terms of monetary expenses incurred during development.

B. INCREMENTAL RELAYING (IR) PROTOCOL

IR protocol bases its principle of operation on the assumption that from the destination there is a channel which provides feedback to the relay. There is always a feedback or acknowledgement message from the destination node to the relay regarding the state of the source message delivery at the destination [48]. The principle utilised in IR prevents re-transmission in case of correct delivery of the message at the destination. Thus, the second transmission will highly depend on the state condition of the channel that exists between the source node and the destination. IR offers a solution to the effective utilisation of the frequency spectrum as explained in [42].

The fixed and adaptive relays that are applied in cooperative relaying display several advantages and disadvantages. Table 1 shows the summary of some advantages and disadvantages.

From Table 1, it can be learnt that fixed relaying have more shortcomings despite the fact that they can be easily implemented. It suffers from higher energy consumption, especially CF and DF, noise and interference being amplified for AF. Adaptive relaying offers more advantages that include spectral efficiency and diversity order in the network. However, the development of adaptive relaying protocol costs more when compared with fixed relaying protocols.

In general the use of relays in networks that are resource strained like M2M communication networks and WSNs

TABLE 2. Advantages that comes with the use relays in cooperative communications.

Advantages on use of relays in CC	References
Increased performance output which comes as a result of reduction in path loss, introduction of multiplex and diversity gains. They all translate into less application of transmission energy and increased capacity	[50][9][44] [51][52][53]
Well distributed quality of service in the network as coverage problems in shadowed areas are solved through relaying technique.	[50][9][54]
Economical technique as there is less infrastructure deployment that enables network operation	[50][54]

comes with several advantages that includes; (1) Optimal energy allocation and bandwidth to users in the network basing on channel state information (CSI) at node; (2) It paves way for network users with varying channel qualities to cooperate and relay messages of each other to the required destination; (3) Coordination and sharing of resources is made possible through cooperation, this helps to improve the quality of transmission and there is less infrastructure deployment. The users in the network that experience severe fading can utilise quality channels made available by other users in the network so as to achieve their required QoS, this is achieved through cooperation. However, the advantages of relay cooperation is based on the channels of the users in the communication network. This means that, relay communication is best only when the source to relay channel is good. Table 2 presents a summary of some of the major advantages in the use of relays in cooperative communications.

PART II: III. CHALLENGES WITH THE USE OF RELAYS IN M2M COOPERATIVE COMMUNICATIONS

The use of relays in cooperative communication has been highlighted in the foregoing discussions. However the utilisation of relays in cooperative communications come with various challenges that are presented in the following sections.

A. REQUIREMENT OF COMPLEX SCHEDULING DESIGN

The implementation of the M2M communication through the use of relays calls for advanced scheduling in order to meet the demand requirements for the heterogeneous traffic users and data relaying in the network. Proper scheduling gives direction on the allocation of resources to each user in this case the relay node and has direct effect on the system throughput. Further scheduling design challenge in M2M communication network arises when considering the Automatic Repeat-Request (ARQ) protocol in the design and Quality-of-Service (QOS) specifications [45]. These two have scheduling processes that have different priorities. With proper scheduling design, the problem of resources over-utilisation is reduced. This normally arises in the system when more channels are required in sending messages from source to destinations, for example N relays requiring N+1 channels. The optimal scheduling can be achieved through the consideration of best-relay selection, incremental relaying and superposition modulation for a resource efficient communication system as evaluated in [55]. However, it is a big challenge when this arrangement is considered for M2M networks.

B. INCREASED OVERHEAD IN COOPERATIVE M2M SYSTEM

The M2M systems that are operating remarkably well need precise handovers, synchronisation, signaling, extra security and resource block allocation. This results in increased overhead in comparison to a system without relaying. The additional overload produces an additional delay in the system since when cooperation is used in M2M communication which has N relays for a TDMA access scheme, the time slots required in sending a signal from source to destination is given as N+1. TDMA is not energy efficient access technology. Further overhead costs are incurred when addressing the security issues of the users. There is need to secure users data to avoid eavesdropping which is a serious challenge when relays are utilised in cooperative communication in M2M [56].

C. INCREASED INTERFERENCE AMONG M2M AND H2H USERS

The relaying scheme for M2M communication solves a number of problems in the network. However, problems of intra and extra interferences arise as a result of the coexistence of M2M and H2H users in the network [57]. The problem of interference in the network culminates in poor system performance. This emerges when the applied power saving approaches, instead of performing the function of reducing the transmission power between the relay nodes, they work to raise the capacity and coverage [58]. Various solutions towards the problems of interference in the M2M/H2H have been proposed [45]. They include Successive Interference Cancellation (SIC) and Zero Forcing (ZF) or Minimum Mean Square Error (MMSE).

Successive Interference Cancellation (SIC) scheme in wireless communication network - It produces an increase Signal to Interference Ratio (SIR) by subtracting the strongest decoded signal from the incoming signal. It suffers from computational complexity, especially with the increase in the number of interferers [Successive interference cancellation in heterogeneous network].

Zero Forcing (ZF) or Minimum Mean Square Error (MMSE) – It can be taken to mean eliminating the intersymbol interference. Under this scheme, the interference cancellation approach involves users using receivers to solve the problem of co-channel interference by the application of the frequency response to the channel that is inverse. Zero forcing approach suffers from the following:

- Received signals may be weak that compensation becomes hard.
- Some zeros may exist in the frequency response of the channels, making it impossible for them to be inverted.

- An infinitely long equalizer is needed for the impulse response.

For the purpose of optimal utilisation of radio spectrum and code assignment that are not readily available, users and relays are coordinated by the central Medium Access Control (MAC) protocol. This introduces maximum utilisation of resources in the network. These proposed techniques are also supposed to be evaluated for M2M communication in massive MIMO, mm-wave communication and heterogeneous networks. The hybrid MAC protocol needs to be investigated together with power control and interference management constraint and select the protocol that optimises the M2M system performance [3]. There can also be an investigation of heterogeneous relay-assisted interference cooperative M2M networks highlighted in [59]. Further optimal utilisation of resources calls for M2M and H2H to have non-orthogonal sharing of resource, this increases efficacy in resource utilisation. However, there is increased interference that needs attention.

D. INCREASED END-TO-END LATENCY

The application of some relaying techniques in M2M communication creates latency in the system. Some operation takes place in two stages, namely reception and decoding [29]. These two processes take place before the signal is re-transmitted to the required destinations. The reception and decoding processes cost time and are not in line with services that are particular about time. Such services include voice and multimedia web services. The delays caused by the relays operations results in poor performance rating in the M2M communication [3]. The other factors that cause increase in latency are: the number of relays and the application of inter-leavers likened to the ones applied in the voice traffic of GSM. There is a need to overcome the latency problem caused by the operation of relays. This can be addressed by advancing to new techniques in relaying to reduce this latency issue. Designers should focus on coming up with new relaying techniques and advanced approaches that could decode signals with reduced latency [60].

E. ADVANCED CHANNEL ESTIMATION TECHNIQUES

The use of relays in M2M cooperative communication comes with several channels of wireless communication that requires several channel coefficient estimation. The many channel estimation process demands for a higher number of pilot symbols for coherent modulation to be engaged. This process is complex in design and a real challenge when it's applied in cooperative communication in M2M.

Further challenge that is closely associated with the channels in cooperative communication is the availability of nodes that are to be utilised in cooperation. The chances of finding nodes that are readily available for cooperative communications without incentives are minimal. The requirement of incentives is a big challenge to the cooperative communication in M2M [25], [45].

F. INTERFERENCE CANCELLATION

The existence of perfect conditions was assumed during the investigation of single relay and multiple relay services for M2M communications. In practical executions, this is never the case where practical relay selection algorithms must be considered. The selection of multiple relays offers several advantages in M2M communications. Such advantages include simultaneous transmission and forwarding of the relayed messages, introduction of coherent combinations such as increased throughput and reduced latency. Nevertheless, the process of selecting multiple relays that produce perfect synchronisation between relays and the required distributed space time codes is challenging. The process calls for further investigation so that proper synchronisation is attained.

In most of the performance evaluation of the relays selection schemes, a single source destination has been considered. The challenging cases that focuses on multiple transmitter and receiver scenario over a single hop and multihop networks is a research area that needs investigation. This will bring out their advantages and disadvantages when applied to M2M communications. Further investigation is needed regarding the exact effect on performance of M2M communication when considering the elevated interference in the network. Elevated interference are signals transmitted through cooperative relays, in one way or another, they have some effects on the performance of the cooperative M2M communications. Some studies indicate that the involvement of multiple relays in source to destination does not introduce meaningful interference in the network. This is more so when considering orthogonal channels where the only effect observed is reduction of spectral efficiency. The effects of interference caused by relays cannot be ignored. Preliminary solutions are explained in [55] and [61] but needs further improvements in order to model the impact of interference on cooperative communication in M2M.

PART II: IV. FUTURE WORK IN THE USE OF RELAYS IN CC IN M2M

This section presents future work in the use of relays for cooperative communications in M2M. There are various proposals put forward that can be examined with the view of achieving the required QoS in the M2M network operations.

The discussions presented in [55] reveals that there are two types of interferences that occurs in cooperative communication. They are co-channel and adjacent channel interferences. For good results that meet the required QoS, there is need to address these two types of interferences through the utilisation of radio resource management schemes [62].

The nodes in the wireless communication network are energy strained, this makes it hard for the network to remain stable in its operation for a longer period of time. This is a big challenge to the network operation and may be solved through the inclusion of feedback system on the relays that allows for power allocation to the nodes. This is referred to as dynamic power control techniques , it is a promising technology that could be a solution to energy problem of the nodes [3], [45]. This approach has been utilised in WSNs. However, the same technique can be examined for cooperative communications in M2M with devices being considered into clusters.

The wide system bandwidth expansion caused by the relay operating in half duplex mode can be eliminated by resorting to the application of the full duplex relaying mode operating in single frequency in the communication network. This calls for the need to find out the full duplex relay mode operation requirements for proper application in the M2M network. The usage of joint full and half duplex communication strategy can also be utilised in cooperative communications in M2M for solving interference problems.

The processing of signals by relays can be achieved through the application of either regenerative mode - signal processing that restores the signal or non-regenerative mode - signal processing that does not restore the signal. The operation of non-regenerative relay mode is less strenuous to the network resources and is more favoured where speed and complexity are factors under consideration, its main Problem is noise amplification. There is need to trim down or shave noise in this operation, this is achieved through the utilisation of orthogonal frequency division multiplexing (OFDM) modulation based on non-regenerative relay system. The application of numerical algorithms discussed in [63] helps in reduction of noise in non-regenerative mode of relay operations when it is applied in cooperative communications in M2M.

It is alluded that the deployment of many relays in the network results in an increase in diversity order, however, it has a negative effect on the spectrum efficiency. This calls for an elaborate design to establish an optimum number of nodes that optimise the network performance in terms of spectral efficiency and diversity order [45], [64]. The utilisation of relays in combination with physical layer network coding (PNC) [65] can be examined for spectral efficiency. Full duplex discussed in [66] is another technique that can be investigated for spectral efficiency in the event of many relay deployment in the network.

The mmWave is specifically associated with 5G. It is hoped that when 5G will be fully rolled out in many countries the communication industry will have achieved a lot as it presents many advantages over other mobile generations. However, due to the regional geography, it is bound to suffer from path loss, shadowing and fading. Further discussions on the propagation of 5g mmWave are tackled in [67]. Therefore, the solution to the challenges introduced by regional geography are the links provided by the relays. They can be modeled for the various propagation environment under mmWave communication.

It is presented in literature that the cooperation among the relay nodes in the communication network is a technique that aims at improving the performance in terms of energy efficiency, spectrum efficiency reliability, scalability and coverage [16], [68]–[71]. The relay nodes in the communication network are energy strained and therefore welcome any energy saving technique. Thus, the cooperation of nodes and the design of cross layer appears to offer a solution to energy efficiency [72]. This is achieved through the implementation and standardisation process which is facilitated by modularity that is provided by the protocol layering. However, layering hinders the advantages introduced by the operation of joint optimisation that occurs across protocol layers of the network. This makes it impossible for the energy in the relay nodes to be used effectively [55]. Further examination is worth being conducted regarding cross layer optimisation and its precise application to M2M networks through the utilisation of cross layer optimisation that considers geographical node disjoint multipath routing technique [73].

The proposals that exist regarding the use of relays in cooperative communication have narrowed their approach on selecting the relay that offers the best results when applied to the single source-single destination relay design. There exists limited research works in literature that have focused on improving energy management in the communication network that have simultaneously considered the best relay selection technique with; multi-source, multi-destination, multi-hop communication relay selection and 5G multiple radio access techniques. It is further observed that in earlier studies carried out, Channel State Information (CSI) was assumed to be always correct. Practically, this may not be true, for example the current multi-path fading is not considered by CSI. Therefore, the research into the appropriate designs that aims at having the best relay selection with channel state information that is imperfect is an area that needs to be addressed for good QoS in cooperative communication in M2M. The design that considers parallel relay, multicast access and broadcast relay channel can be considered for cooperative communications in M2M [38].

Future work should consider the introduction of incentive schemes and fairness in coming up with the most appropriate relays that can be utilised in network that fit the following description ; those that are heterogeneous in nature, those made up of massive MIMO or mmWave communication, M2M communications that are energy strained and those involving relay nodes whose management is by various network operators [74], [67].

The 5G enabling technologies such as full duplex, energy harvesting, massive MIMO and mmWave communication have been applied in fewer studies as shown in [1] and [75] for device-to-device (D2D) communication. However, the combination of these technologies with either power control or interference cancellation can examined for cooperative communications in M2M. In the analysis of relay operation it is always assumed that relays usually perform the function of forwarding data that originate from the source only, this is not always the case. When considering the operation in user cooperation that involves the sharing of resources, user's terminal performs the function of forwarding its own data and other user's data to the destination [45], basing on these observations, its worthy to consider how to prioritize data

TABLE 3. Fixed Relaying: improvement approaches.

Type of fixed relay	*Appropriate actions to improve on energy and spectral efficiencies in fixed relays*
AF [33]][[77]] [78] [79]	Use of hybrid of two or more relays, thus the application of full duplex or half duplex in the operation, apply IR that has feedback mechanism in its operation.
DF [79]][25]]	Consider selective DF relaying scheme that takes into consideration the fading coefficient. Apply DF that is adaptive in nature so that a signal is sent only when decoding can be attained correctly, adopt full or half duplex approach, and positioning the relay closer to the source of the signal.
CF [77] [79] [80]	Use of hybrid of two or more relays- application of full and half duplex relays, apply IR that has feedback mechanism, and utilisation of Compute-Compress-and-Forward (CCF) strategy which has reduced forwarding rates that is made possible due to the additional compression section.

transfer from various network users. Further research needs to investigate the concept of bidirectional user for cooperative communication in M2M which is addressed in [76] for cognitive networks.

Fixed relays implementation procedures are less complex, however their overall performance is not satisfactory. Presented in table 3 is a summary of approaches that can be applied to fixed relays in order to raise their performance in energy and spectral parameters.

PART III. CLUSTER BASED CC IN M2M NETWORKS

The grouping of communication devices to form clusters brings in several advantages in the communication networks. One major advantage is energy efficiency that is achieved through the reduction in transmission power and reduced collision at the network access point. Under clustering organisation , the access to the network is through the cluster head that aggregates all the data of the cluster members [81]. Clustering protocols specify the topology of the hierarchical non-overlapping clusters of sensor nodes in the network. A dynamic approach to clustering is quite important for self-organising sensor networks (SON). An efficient clustering protocol ensures the creation of clusters that are characterised with the radius that is similar and perfectly positioned cluster head to serve all cluster members with fairness. All nodes in the network that is clustered are linked to the cluster head. The cluster head find their own appropriate routes in the network. When considering a sensor network that is covering a wide area, clustering approach will reduce complication in the network. There will be multi hop linkage establishment and reduction in the number of transmission when it is compared with the network that is not clustered [82]. The application of clustering technique in M2M communications networks brings about more efficient gathering of data and higher network energy efficiency for the energy strained nodes like that investigated in [83].

The direct communication between devices and BS in a large M2M communication network results in great data congestion and collisions at the access point. This results in power wastage and draining of the energy from the devices faster. Therefore, clustering is employed in the system to minimise some of these weaknesses. When considering clustering technique, in each cluster group there is election or selection of the Cluster Head (CH). The other normal devices in each cluster group have a direct link with their respective CH where they forward their data. The forwarded data is aggregated by CH which is then forwarded to BS. The advantage of increased efficiency in data transmission achieved through the reduction in the number of devices that try to reach the BS is achieved through clustering technique. The Wireless Sensor Networks (WSNs) share some features with M2M communication networks that includes; large numbers and being battery-operated. The cluster design technologies are being advanced day by day with the aim of improving QoS in the communication networks.

There are many approaches regarding clustering with varied application in engineering. However, majority of the researchers still adopt the initial published work on cluster formation through conversion of networks from flat to cluster by role assignment. Cluster Head (CH) – This a node that has higher residual energy and communicates with nodes of the cluster and BS. Cluster-node- (CN) - node that is a member of the cluster, gateway (GW) – it is one of the CNs which belongs to one cluster and performs the function of linking two CHs. Most approaches have considered election of CHs first based on some set criterion and then other nodes align accordingly. The CN that links clusters automatically become gateway [84]. The classification of clustering protocols in this survey will broadly be divided into two groups;, centralised and decentralised clustering.

PART III: I. CENTRALISED CLUSTERING PROTOCOLS

In centralised clustering, sensor nodes present their individual characteristics such as residual energy and position in the network to the BS. Through established sequence of operation the BS works out the following parameters: number of clusters, size of clusters and location of cluster heads. The BS goes further in assigning of duty to individual nodes [85]. The two major examples under this class of clustering are Low Energy Adaptive Clustering Hierarchy-Centralised (LEACH-C) [86] and Power-Efficient Gathering in Sensor Information Scheme (PEGASIS) [87], [88]. The aim of centralised clustering is to come up with low maintenance clusters [89] through the process of grouping mobile nodes that have similar or closer characteristics being put into the same cluster [90]–[92].

In the sensor networks, it is assumed that there are many nodes and therefore the operation of central clustering where the BS has to go through all those procedures of information collection before allocation processes is time consuming and hence not practical for a network that is dense and covering a large geographical area and also energy consuming. Due to this, the centralised approach of clustering is not meant for a large communications network as it is the case in M2M communication networks. The process of clustering devices should take place without them knowing their position in the network in relation to the BS and should not be dictated by the BS. At times location-finder devices are deployed to perform the task device location in the network, they are often either costly or add too much overheads.

A. LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY-CENTRALISED (LEACH-C)

The process of setting up clusters by LEACH-C protocol resembles LEACH protocol when each round is considered during starting. While in LEACH, the stochastic algorithm is applied by the nodes to find which one becomes the CH, in LEACH-C an algorithm which is centralised is operated by the sink. As it is with the operation of central clustering, the collection of information and allocation of roles is performed by the sink [93]. LEACH-C algorithm is quite sensitive to the sink location. It is true that the performance of LEACH-C will deteriorate immediately the cost of energy for communicating with the sink will rise to be more than the energy involved in cluster formation. Assuming that the location of the sink is far from where the majority of the nodes of WSN or M2M devices, more energy will be consumed in the network. The performance of LEACH-C suffers because it depends on the position of the sink [94]. It is one of the solution to cooperative communications in M2M however its dependence on sink location works against it in terms of energy efficiency when considering a network of vast geographical area.

B. POWER-EFFICIENT GATHERING IN SENSOR INFORMATION SCHEME (PEGASIS)

As opposed to other clustering protocols like LEACH, PEGASIS does not create clusters. Instead, chains are constructed which helps in eliminating the overhead problems that are associated with clustering. The operations that exist in PEGASIS that is described as being chain based shows that the communication of nodes is based on how close they are to each other which is now called neighbour, the communication is from one node to the other up to the time the summed up data reaches the BS. Though this protocol suffers from redundancy problem, it can be one of the solution to the cooperative communications in M2Msince it does not follow traditional clustering procedures which contributes to energy consumption [87]–[88].

PART III: II. DECENTRALISED CLUSTERING PROTOCOLS

This section presents some of popular protocols that are associated with decentralised clustering that are applied in communication networks. This class of clustering protocol is not influenced from the sink point. Thus, clusters are formed without the direction from the sink/BS as is the case with centralised clustering. The starting point in the development of a clustering algorithm that is energy efficient starts off with each node in the network having a probability say p of being a CH. Each node advertises itself to other nodes within the range of k hops to the CH. In a WSN the transmission range has limitations as the number of levels in hierarchical structure increases. Thus, the increase in the number of hierarchical levels means that the communications between the CH of the upper-level will not be possible with others [85]. The following are some of the examples of decentralised clustering protocols that are used in WSNs that can also be examined for cooperative communications in M2M networks under clustering approach: Low-Energy Adaptive Clustering Hierarchy (LEACH) algorithm [86]. Decentralised Energy Efficient Cluster Propagation (DEEP) protocol [95]. Hybrid Energy Efficient Distributed Clustering (HEED) [96], [97] and Energy Efficient Hierarchical Clustering (EEHC) [96], [98].

A. LOW ENERGY ADAPTIVE CLUSTERING HIERARCHY (LEACH)

LEACH which is described as being a TDMA based medium access protocol is one of the examples of the decentralised clustering protocol that was designed to lower the energy consumption in the WSN and hence prolong the network life time. It also utilises code division multiple access to reduce interference between clusters. LEACH operates by periodic re-clustering and change of the network topology. Basically, it consists of two phases, the clustering and state steady that takes place during each round in its operation. The operation that results in the selection of CH is as follows - a number between 0 and 1 is picked at random by the sensor node and it is compared with T (n), T (n) – is called the calculated threshold. The results is that when T (n) is larger than the number that was randomly picked by the node, then the node becomes a cluster head for that current round. In LEACH, the role of CH is to receive and aggregate data from other members of the cluster before forwarding to the sink. LEACH protocol randomly assigns priority values to nodes who are members of the clusters; these nodes through periodic rotation will become CH. Thus, LEACH protocol practices CH head rotation to curb depletion of energy levels in the CHs. The main characteristics of LEACH can be summarised as a protocol that exhibits cluster CH rotation and data aggregation. The foregoing presentation though having been applied to WSN could form one of the solutions for cooperative communications in M2M network. Nevertheless, the process of applying random approach to CH rotation does not guarantee the best energy efficient topology since the process can easily pick on the node whose energy consumption is very high or one with very low residual energy [84], [86].

The creation of clusters in LEACH protocol depends on the transmission power utilised by the nodes in the network to reach the created CHs. As it has been shown in the paragraph above CHs have been created; the remaining nodes that are not CHs locate their cluster group through the process of linking themselves to the CH to which they will reach with the minimum transmission energy. In order to balance the load there is periodic rotation of CH among the nodes in the clusters. In LEACH protocol each sensor is able to communicate directly with the CH and BS through one hop intra and inter cluster topology.

The propagation model used in LEACH is free space model which does not favour the networks that cover a wide area. Thus, some drawbacks associated with LEACH protocol can be summarised as: the periodic random changes of the CHs, the assumption that nodes remain at one position in the network and the assumption that nodes can have direct link to the sink has a negative effect to network scalability [97].

The constraint associated with LEACH are partially addressed by Hybrid Energy Efficiency Distributed (HEED) [64]. This protocol is where several factors are considered in the selection of the CHs, the approach is considered to be full of probabilities. In the selection of the CH, the main parameter under consideration is the battery level of the nodes. However, the transmission power to the neighbours is also considered in the probability computation for the node to be selected as a CH. The re-computation of probabilities to enable the selection of a CH is a periodic exercise; after re-computation, re-assigning of the CH roles is performed. These processes take place because the battery level of the nodes is not static. This is an advantage in the network as it results in an equitable distribution of energy burden between nodes [84]. Further improvement of LEACH protocol is revealed in [99], the authors presented an improvement in the CH selection that is superior to random and an alternative approach in the creation of clusters in the network.

B. DECENTRALISED ENERGY EFFICIENT CLUSTER PROPAGATION (DEEP)

DEEP protocol though having been utilised in WSN could be an appropriate solution to the cooperative communications in the M2M. The protocol is able to address energy issues in WSN as communication of data continues. The formation of clusters is based on the pre-selection of the initial CH which then starts the process of advertisement to other nodes in the network.

By considering relative distance that exists in between nodes and the residual energy, the initial CH establishes members of the cluster and potential new CHs. The performance of this model presents load stabilisation between the CHs in the network [95].The energy losses that occur in other protocols associated with predominant re-clustering are cut out as explained in [95].

C. HYBRID ENERGY EFFICIENT DISTRIBUTED CLUSTERING (HEED)

This protocol offers some advantages in the WSNs based on its multi-hoping techniques of operation. The same advantages enjoyed in WSNs are likely to be experienced in the M2M when the protocol is applied. Thus, HEED is listed as one of the solutions to the cooperative communications in M2M under clustering protocols. The selection of the CHs is based on two main factors, the residual energy and intra cluster communication cost. There are two components that make up the function intra-cluster communication cost. These are the size of the cluster and the closeness of a sensor to its neighbour. In this protocol a sensor with high residual energy has the potential of becoming the CH. Thus, it could be summed up that for the selection of CHs in HEED protocol, hybrid of energy and communication cost are considered. It is further noted that there is no random selection of CHs in HEED [28]. HEED considers the CHs reselection, but its intra-cluster communication function does not mention propagation model. HEED is restricted to networks that are not dynamic in nature and it also suffers from its complex approach in the selection of the CH [96], [99]. However, its general performance is superior to that of LEACH in terms throughput and packet management. Other advantages of HEED emerges when dense WSNs are considered. They include reduction in packet drop, energy consumption and overall delay.

D. ENERGY EFFICIENT HIERARCHICAL CLUSTERING (EEHC)

EEHC is presented in [96] and [98], it is an algorithm that has been applied in WSNs under clustering approach. The same clustering protocol can be extended to cooperative communications in M2M. It operates in such a way that the energy load is balanced in the sensor network as well as minimising energy consumption. The processes of cluster formation is as follows; first it utilises a mathematical derivation in finding the optimal quantities for p and k. Where p - the probability of each sensor becoming a CH and k is the number of hops to the CH. This is the starting point of ensuring that there is minimisation of energy consumption in the network. The key point of this mathematical approach lies in finding p and k quantities that paves way in determining the function that describes the energy consumption in the network during data transmission. The precise values of p and k quantities are factors that minimise energy consumption in the network. With a probability p and inside the radio range, each node broadcasts itself as a CH. The nodes in the range of k hops receive the broadcast directly or through the process of forwarding. When a sensor that is not a CH receives the broadcasts, it qualifies to be a member cluster that is closest. EEHC is a multi-hop type of clustering algorithm whose energy consumption function does not consider the wireless propagation model. It's further observed that EECH does not mention how CHs reselection is performed. This means that under EEHC protocol, the battery of CH will be exhausted very fast as discussed in [100].

Some of the clustering protocols that have been considered in the foregoing paragraphs are widely applied in WSNs. The same protocols can be examined for cooperative communications in M2M. However, during their applications, they present the following advantages and disadvantages; for the centralised clustering the advantages include even distribution of CH in the network, and in general provide solutions that are global and optimum [101]. The disadvantages includes high communication delays and high energy consumption. Regarding the decentralised clustering, advantages

TABLE 4. Shows a summary of the advantages and disadvantages of the clustering schemes discussed in Part II

Type of clustering scheme	*Examples*	*Advantages*	*Disadvantages*
Centralised based clustering	LEACH-C [93]][94][101]	CH dispersed uniformly in the network. solution obtained is globally optimum	Higher energy required to start up, more energy is used for transmission for the nodes that are located far from the BS.
	PEGASIS [87]][88]	Has superior results in energy management and life extension of networks.	Extreme communication delays, incompatible for networks with time fluctuating topology, Sensor nodes die early, Network not scalable.
Decentralised based clustering	LEACH [86]	Prolongs the lifetime of network, CHs aggregates the Data packets and transmits to the sink/BS.	It experiences robustness issues like failure of the cluster heads, no inter-cluster communication, CHs are not uniformly distributed, and CH selection is a random process. CH always on.
	DEEP [95]	No need for location-finder hardware, low communication cost a good energy distributor.	It exhibits good performance only when nodes are distributed evenly. It assumes that all nodes are equal in all aspects.
	HEED [96] [99]	High throughput, less energy consumption in dense network.	Limited to static networks, complex approach in CH selection.
	EEHC [96] [98]	Reduced energy consumption in the network as p and k are mathematically derived.	CH battery exhausts fast.

include prolonged network lifetime, high throughput and high energy efficiency. Some of the disadvantages include random selection of CHs, limited to static networks non-uniform distribution of CHs and since its operation is based on local information its performance is locally optimal [101]. Table 4 presents some of the advantages and disadvantages of the centralised and decentralised clustering schemes.

PART III: III. CHALLENGES WITH THE USE OF CLUSTERS IN CC IN M2M

Although most of the clustering protocols presented have been investigated in WSNs, it is reckoned that the same protocols can be extended to cooperative communications in M2M. This section presents some of the challenges associated with clustering protocols when they are executed in M2M cooperative communications.

The performance of a clustering protocol in terms of offering good results in terms of energy management, packet delivery and above all extension of network lifetime depends on a well organised approach towards creation of efficacious clusters. However, with the expansion of the networks that are bound to cover large geographical areas, creation of potent clusters tends to be hard. The created clusters performs below par. Thus, the vast geographical areas and the unplanned node distribution stands against effective clustering procedures, it becomes a challenge when it is considered in cooperative communications in M2M.

The fundamental nature of the M2M devices in the network is described as being heterogeneous. Thus, some devices have low capabilities while others are very advanced. This aspect complicates the clustering protocols that assumes uniformity of all the devices.

The creation of uniform clusters hinges on the even distribution of the nodes in the network, this is practically impossible. It can be alluded that uniform cluster formation is far-fetched especially for M2M devices in the network.

Some other challenges aligned towards specific clustering protocols include redundancy. This is observed in PEGASIS clustering protocol which outperforms LEACH due to the elimination of overhead caused by dynamic formation of clusters, minimization of transmit energy of non CH nodes and the utilisation of one transmission to the BS/sink per round [102]. Nonetheless, it exhibits redundancy during its operation that needs to be addressed for it to produce optimal results in the M2M network. For LEACH, the propagation model used is free space model, this is not appropriate for the networks that cover a wide area like M2M networks. Other challenges include the periodic random changes of the CHs and the assumption that nodes remain at one position in the network.

PART III: IV. FUTURE WORK IN THE USE OF CLUSTERS IN CC IN M2M

Multi-criteria clustering approach could be an option worth being considered in the process of creating clusters and selection of CHs. All the advantages enjoyed in the use of clustering protocols in WSNs which can be extended to M2M networks hinges on how the clusters are instituted. Under multi-criteria clustering protocols several factors are considered concurrently. Some of those factors include – node mobility, location of nodes in the network, number of neighbours and energy states of the nodes.

Energy efficient clustering in M2M devices for massive access management and energy efficiency can be jointly considered with network lifetime and energy cost in a number of simultaneous accesses to the base station and energy consumption of machine to machine devices. This cooperative approach with precise design can yield desirable results.

The adaptive QoS clustering technique that invokes incentives to the elected CHs can be examined for M2M communications. It may be examined as a technique in radio resource management in M2M devices that have varying

QoS demands and specific data for transmission. The technique is a modification from that discussed in [100] and [103] for WSN.

Hybrid clustering protocol can be investigated in relation to its application to M2M communications. This involves marrying of protocols so that the benefits of each can be exploited. Improvement of the existing one can also be adopted as it is investigated in [104], where an optimisation LEACH was developed to improve the performance of existing LEACH and LEACH-C for wireless sensor networks. The same can be conducted in M2M communications with consideration of varying abilities of the devices.

The application of mixed clustering where two schemes, centralised and the distributed clustering can be adaptively used for M2M communications. An example is described in [105] where PEGASIS and LEACH are considered for WSNs The design should consider the stage at which each should be applied in order to get optimal results.

The application of coalition game with energy incentives can be examined for cooperative communications in M2M. This will be a modification of the cooperative communications scheme based on coalition formation game discussed in [106].

PART IV CONCLUSION

This paper has discussed solutions, challenges and future work in cooperative communications in M2M. The discussion divided cooperative communication into two parts: use of relays and clusters. In the use of relays for cooperative communications, fixed and adaptive relays were presented. Fixed relays had the advantage of being simple in design, less expensive in implementation and have higher achievable rate. However, they suffer from low energy and frequency efficiencies. On the other hand, adaptive relays enjoy the advantage of having high energy and spectral efficiencies when compared with the fixed relays. They also offer high diversity order at the destinations. Despite the mentioned advantages, adaptive relays are expensive to implement. Further presentation on use of relays focused on the challenges that included increased end-to-end latency, increased overhead in cooperation, complex scheduling requirements, interference cancellation just to mention a few. Use of relays presentation concluded with the section of future work. Under future work, co-channel interference, cross layer optimisation and effect of full duplex relay operation were presented.

Use of clusters was discussed starting with an overview of clustering. Advantages of clustering include reducing transmission power and reducing collision at the access points. They all aim at energy efficiency in the network and QoS improvements. Clustering schemes were classified as: centralised or decentralised and examples in each case were given. Classification of clusters based on the operation design was discussed. The challenges in use of clustering protocols included difficulties in creating clusters. This is when the distribution of nodes in the network is uneven and more so when the network is covering a wider area. The presentation on use of clusters ended with proposals of future work that included; multi criteria clustering, hybrid clustering techniques and adaptive QoS clustering that invokes incentive as techniques that could be considered to bridge the gap in the discussed challenges. In summary, cooperative schemes despite some challenges involved such as their complex set up and operations, can offer better solutions to M2M networks in terms of energy efficiency, reliability and scalability when further modifications are exploited in the design [107].

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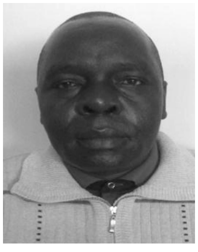

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