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Proposed different relay selection schemes for improving the performance of cooperative wireless networks

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ABSTRACT

Relay selection is a new method currently used to develop and improve cooperative wireless networks. One of the main advantages of this new technology is that it can achieve cooperative diversity gain without installing multiple antennas in the transmitter or receiver. Relay selection algorithms can be used to select one node to become a relay node from a set of N candidate relays with optimization criteria as the outage probability or frame error rate. The selection process is preferable to operate in a distributed fashion and offers only reasonable costs in terms of manufacturing complexity and flexible handling over wireless cooperative networks. In this work, different relay selection schemes are proposed to enhance the cooperative wireless networks in terms of different approaches including: 1) relay selection-based destination feedback scheme, 2) relay selection based a ready-to-send/clear-to-send (RTS/CTS) messages scheme, 3) relay selection-based identification messages (IDM) table scheme, and 4) relay selection-based relay power consuming scheme. The experimental results via suggested case study show that the performance of overall cooperative network is enhanced in terms of increasing throughput, energy saving (efficiency maximization), blocking reduction and outage reduction (PER minimization).

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1. INTRODUCTION

Cooperation in wireless communication plays a major and pivotal role in developing and improving the durability of interoperability on a large scale by taking advantage of the spatial diversity of multiple parties [1], [2]. Modern cooperation technologies are the right basis for researchers and institutes to develop the future wireless networks. Cooperative relaying is an untapped tool of achieving performance gains in wireless systems, both in the context of cellular migration optimization systems and ad hoc networks [3], [4]. The primary building block for this technology is relay: the source node relays a message to a destination; A third node hears this transmission and forwards (relays) the message to the destination; finally, the destination combines the two received messages to improve decoding [3]-[5]. The maximum throughput that can be achieved for the relay channel is higher than the source and destination direct transmission and non-cooperative relay of source and destination [6], [7]. Instead, the same throughput is obtained using less energy.

The procedure of relay selection is done as follows: A source node (S) wants to send a message to a destination node (D). There are some neighbors nodes among S and D, which they can be select to play the role as cooperative relay node. Relay selection specifies the node that is "best suited" to work as a relay R. Source node (S) sends a ready-to-send (RTS) message, which is received by D and all other neighbors of S (relay nodes and the destination). Upon reception of the RTS, node D sends back a clear-to-send (CTS) message. Also the neighboring nodes (relay nodes and the source) will receive it. Each relay node set a timer with an interval (Ti) according to the received signals power (Ps = RTS power and Pd = CTS power) where Ti proportional inversely with Ps and Pd. Note that the node with the smallest Ti, is the best candidate as a cooperative relay. The optimal candidate node's timer counts down and expires firstly. After timer = 0, this selected node will transmit an apply-for-relay (AFR) packet to all neighboring nodes (the other relay nodes, the source, and the destination) will receive AFR, and the other relay nodes will clear their timers, so that only the first node (Ri) with smallest interval will cooperate as a relay node. After receiving AFR, the destination sends acknowledges with a select-for-relay (SFR) message. Then the transmitter after receiving AFR and SFR is notified of the relay node and can start sending payload data. It will send the data with the node Ri as cooperative relay to the destination.

Our contribution of this work according to formulate different cooperative relaying scenarios where we considered some conditions that can achieve realistic environment properties. We propose sub-optimal power allocation algorithm at the cooperative path to help deriving the efficient strategy of forwarding receiving signal from source to the destination and would achieve the maximum diversity of N+1. We also investigate the effect of packet error rate (PER) on the energy and we propose different conditional amplify-and-forward (CAF) schemes including: 1) relay selection based destination feedback scheme, 2) relay selection based RTS/CTS messages scheme, 3) relay selection based identification messages (IDM) table scheme, and 4) relay selection based relay power consuming scheme to optimize PER and maximize the energy efficiency.

Explaining research historically, including research design, research procedure (in the form of algorithms, Pseudocode or other), how to test and data acquisition [1]-[3]. The description of the course of research should be supported references, so the explanation can be accepted scientifically [2], [4]. Past researches in cooperative communication techniques are majorly based on single antennas relays as in [8]-[12]. Bletsas *et al.* in [13] propose the idea of relaying selection in which only the optimal single relay is selected for assisting the source transmission. Later in [14], Beres and Adve present another relay algorithm of selection known as "selection cooperation" that focus on decode-and-forward (DF) cooperative network. While, Madan *et al.* [15] study cooperative networks with relay selection scheme using AF or DF protocols over Rayleigh fading channel, they claimed that the relays are perfectly regenerate the information transferred from the source even if the source-to-relay links may work at a predefined probability of bit error (BEP). Since, it is known that AF is constrained by noise amplification. While DF limited by error propagation, therefore a selection between AF and DF may be sufficient in term of symbol error probability. Ibrahim *et al.* [16] have compared between the selection protocol between AF and direct-transmission (AF-DT) outperforms as well the fixed AF and DF relaying systems. While Kadhim [17] present that in case the source-relay link coefficients are below a certain threshold, the relay is still idle.

The work [18] analyzed and evaluated the performance of cooperative wireless networks for AF mode over the fading channels where these channels are independent and non-identical (i.n.i). This work achieved interference suppression for each relay in order to reduce the impact of multiple access interference. Consequently the outage probability is obtained using CDF for the whole SNR at the base station. Then, defined approximate bound for AF relaying in order to derive the PDF of the whole SNR so the outage probability can be calculated.

The works of [19], [20] proposed to use an adaptive decode-and-forward (DF) relaying to evaluate the performance of uplink cooperative wireless cooperative systems over fading channels. The outage probability for a multi-relay system with best relay selection scheme was derived. This work is done with the moment-generating function (MGF) for the total SNR at the base station, so that the cumulative density function (CDF) is also done. Then the asymptotic performance of the system at high SNR was examined to evaluate the achievable diversity gain for different system parameters.

The work of [21] evaluated the performance of cooperative diversity networks using AF relaying mode over independent and non-identical fading channels. The performance's error rate and the outage probability are given using MGF as well as CDF and PDF of the total signal-to noise-ratio (SNR) at the base station. The results of this work proved that the derived performance's error rate and outage probability are recommended lower bounds significantly at middle and high SNR. This work considered Maximal Ratio Combining at the destination with AF relaying to in order to obtain the exact error rate and the outage probability.

Torabi *et al.* [22] presented the analysis and evaluation for cooperative diversity networks with relay selection scheme over Rayleigh fading environment. This work gave analytical expressions for the cumulative density function (CDF), probability density function (PDF) and the moment generating function (MGF) of source-destination signal to noise ratio (SNR) for the model under consideration for independent identical (i.i.d) and non-identically distributed (i.n.d) fading channels. Then these expressions are utilized to obtain lower bound closed form expressions for the average symbol error rate (SER), the outage probability (Pout), and an upper bound closed form expression for the average channel capacity. In this work the numerical analysis of the mathematical expressions is used to get the system performance under different states, then these expressions are evaluated and compared for both independent identical (i.i.d) and non-identically distributed (i.n.d) fading links.

2. RESEARCH METHODOLOGY

In this section, it is explained the results of research and at the same time is given the comprehensive discussion. Results can be presented in figures, graphs, tables and others that make the reader understand easily [23]-[25]. The discussion can be made in several sub-chapters. Wireless network diversity is a realistic development of cooperation technologies for spatial diversity systems, whereby the antennas are positioned in the next hosts distributed in space compared to the first source antenna or receiver in traditional spatial diversity systems such as collaborative systems that greatly enhance diversity gains. Wireless cooperative communications leveraged to exploit the spatial diversity of multiple nodes to maximize the use of the wireless bandwidth and the quality of wireless services. In particular, wireless stations can take advantage of transmitting messages to one another to spread the same signals across multiple paths in the network.

Let's consider that our wireless cooperative network model constitutes from a source (S) node which transmits a signal to the destination (D) node via the cooperation of N relay nodes whereas ($i = 1, 2, 3, \ldots, N$) as shown in Figure 1. We assume each relay node at our network model attached with a single antenna and we assume also that all relay nodes have to work in half duplex mode, and then let h_{SD}, h_{SR} and h_{RD} are the channel coefficients from source node to destination node, source node to relay node and form relay node to destination node respectively.

Many schemes [26], [27] of cooperation can be divided into three famous approaches or systems such as amplify and forward (AF) relay as shown in Figure 1 (a), decode and forward (DF) relay as shown in Figure 1 (b) and compress and forward (CF) relay as shown in Figure 1 (c), the CF relaying schemes are noticed to the cases which the relays forward quantized, compressed or estimated versions of its observation to the destination [28]-[30].

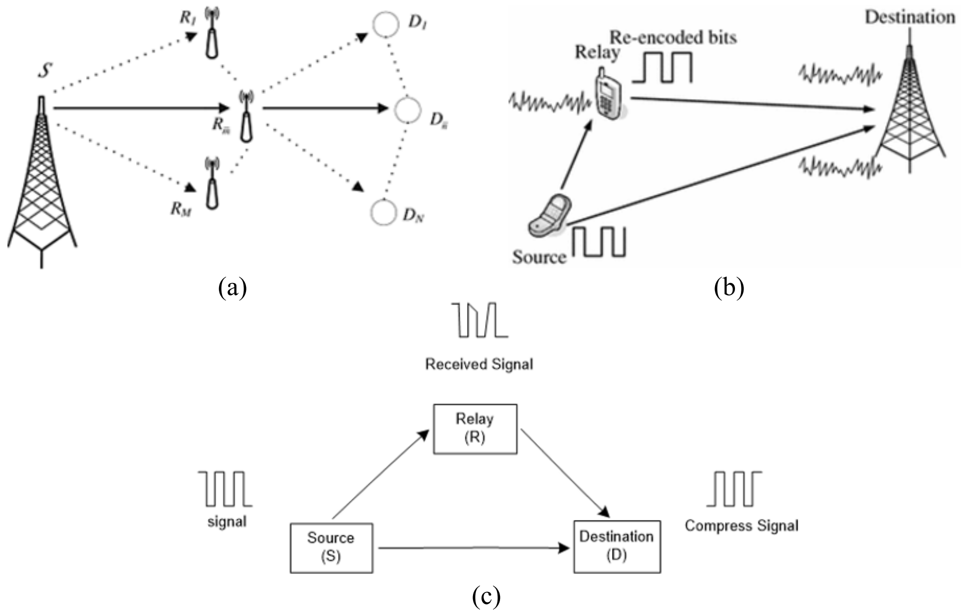

Figure 1. Different approaches of relay cooperation: (a) amplify and forward system (AF), (b) decode and forward system (DF), and (c) compress and forward system (CF)

3. PROPOSED RELAY SELECTION SCHEMES

Cooperative diversity can be provided without the need to implement multiple antennas on small communication terminals. By utilizing relays as virtual antennas between source and destination the full diversity is achieved. Cooperative diversity is a cooperation with virtual antennas for improving, network capacities. In cooperative diversity the circling nods act as relays to assist in forwarding the data to the destination and so achieving full diversity. Relay selection algorithms can be accomplished by assisting the intermediate nodes called relays. At the destination the receiver detects the total data from all the transmitted signals from the source and one or more relay nodes; with the help one of combination relay selection techniques that will be discussed in the next subsections. Figure 2 shows our contributions schemes through proposing different relay selection algorithms that may be improve cooperative diversity gain and then network performance.

These proposed schemes are including: 1) relay selection-based destination feedback scheme, 2) relay selection based RTS/CTS messages scheme, 3) relay selection-based identification messages (IDM) table scheme, and 4) relay selection-based relay power consuming scheme. Figure 2 as shown is the conceptual diagram of our proposed relay selection schemes which play an important role to enhance the conventional relay selection scheme so as the performance of wireless cooperative network is improved in terms of efficiency maximization, packet error rate (PER) minimization and blocking reduction.

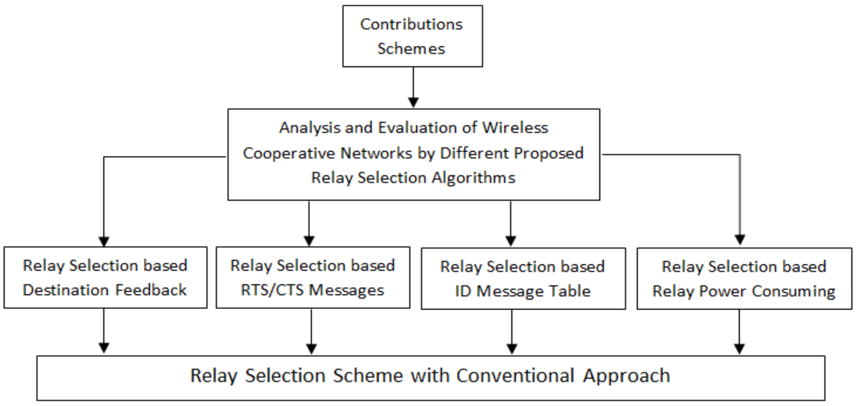

Figure 2. Contributions schemes through proposing different relay selection schemes

3.1. Conventional relay selection scheme

In this work, we have done some contributions to the cooperative wireless network research area, especially in relay selection; we aim to propose different relay selection models for performance evaluation of efficient cooperative networks through adaptive relaying communication protocols for wireless multiple relay networks in terms of analysis that can be used in AF. The following procedure shows the steps of how the conventional relay selection scheme is working:

- The transmitter (S) sends RTS (Figure 3 (a)).
- All neighboring nodes (relay nodes and the destination) will receive it.
- The destination (D) sends CTS (Figure 3 (b)).
- The neighboring nodes (relay nodes and the source) will receive it.
- Each relay node set a timer with an interval (T_i) according to the received signals power (P_s=RTS power and P_d= CTS power), where T_i proportional inversely with P_s and P_d. that means; T_i = arg ($1/P_s$, $1/P_d$). Where the node with the smallest T_i is the best candidate as a cooperative relay.
- After T_i reaches to zero, the node R_i sends AFR as shown in Figure 3 (c).
- All neighboring nodes (the other relay nodes, the source and the destination) will receive AFR.
- The other relay nodes will clear their timers, so that only the first node (R_i) with smallest interval will cooperate as a relay node.
- After receiving AFR the destination sends SFR (Figure 3 (d)).
- The transmitter after receiving AFR and SFR, then it will send the data with the node R_i as cooperative relay to the destination (Figure 3 (e)).

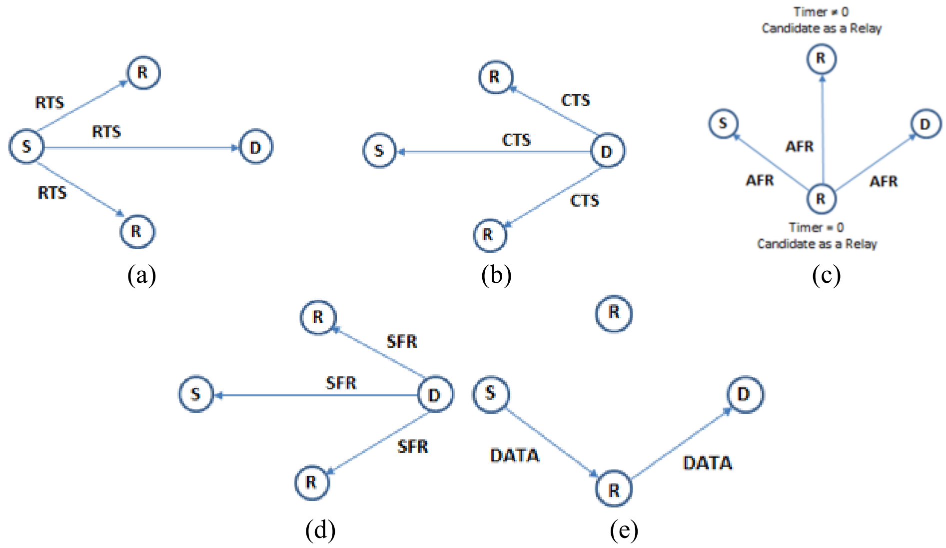

Figure 3. Conventional relay selection scheme procedure: (a) S sends RTS, (b) D sends CTS, (c) Ri sends AFR, (d) D sends SFR, and (e) S sends DATA to D

3.2. Relay selection-based destination feedback scheme

In this relay selection scheme, the relay choice selection is decided by the destination and its requirements for network's QoS. The selection process depends on two metrics: packet error rate (PER) and error threshold value (ETV), this error value describes that if the destination can receive and decode packets correctly and quickly. So, in this way the relay can be selected to pass the data from source to destination smoothly. The following steps show the work procedure of this selection scheme (Figure 4):

– The destination measures PER from RTS message.
– If PER < ETV, this means that the destination can receive and decode packets correctly; therefore, it sends acknowledge message (ACK).
– All relay nods will clear their timers and then stop the cooperation process after receiving ACK.
– The source starts direct transmission to the destination as a response to ACK.
– If PER > ETV, this means that the destination cannot receive and decode packets correctly; therefore, it will select a relay by sending SFR as a response to AFR.

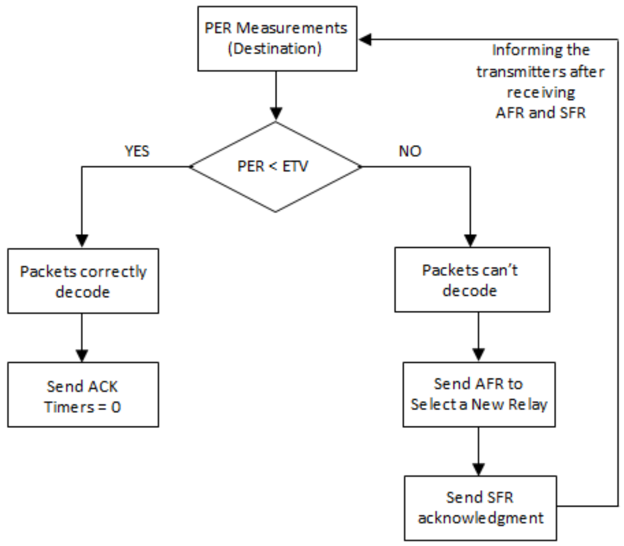

Figure 4. Relay selection-based destination feedback scheme

3.3. Relay selection based RTS/CTS messages scheme

The selection process here depends on the received RTS and CTS messages at each relay node cooperated in wireless network and gradually the number of relay nodes is reduced and then the competed nodes to serve as relays are reduced which means the probability of to select the appropriate relay node is increased. Again the process of this relay selection scheme is depended on PER and ETV values. The procedure work of this scheme can be described into the following steps (Figure 5):

– According to the received RTS and CTS, the number of relay nodes that competed for cooperation process can be eliminated.
– If a node has PER > ETV (error threshold value) for any of RTS or CTS, then it will not enter the competition for relay selection process.
– Uses this enhancement will reduce the number of competed relays, and then eliminates power consumption and reduce nodes overhead.

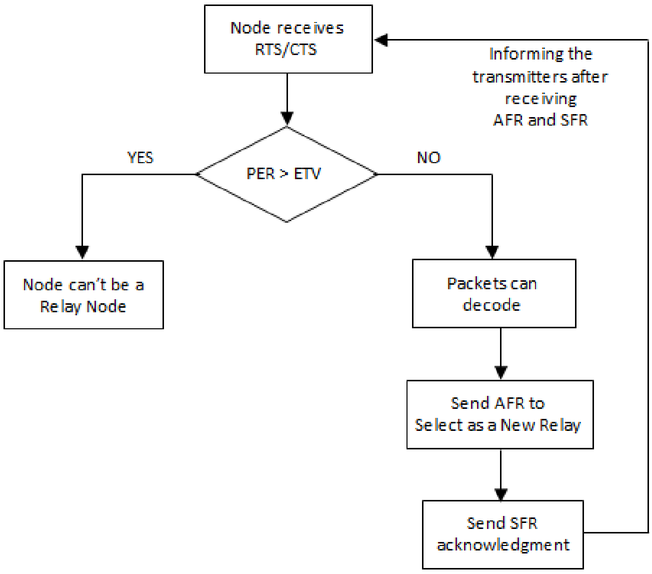

Figure 5. Relay selection based RTS/CTS messages scheme

3.4. Relay selection-based IDM table scheme

This scheme of relay selection is depended on constructing identification message (IDM) table for each relay node (i.e. each node has its IDM table). By the way, each relay node needs to update its IDM table periodically in order to be up-to-date with the network changes including instantaneously joining or leaving nodes. So, this relay scheme includes two important procedures (IDM table construction procedure and transmission procedure). We must put in our mind this standard basis: If the destination cannot overhear RTS due to its location out of transmission rang of the source or obstacles, so it cannot send CTS.

3.4.1. IDM table construction procedure

The following steps describe the IDM table construction for wireless cooperative networks to include new updates of relay nodes changes; we suppose a single hope relay cooperation approach:

– Any node enters the network, it will send Identification message IDM as shown in Figure 6.
– IDM message contains time stamp entity.
– Any node within the transmission range will receive this IDM message.
– Each node has its IDM table that contains IDM and time stamp entities for each neighboring node.
– IDM table updated according to new IDM messages, or subsequent data transfer and periodically.
– Subsequent data transfer update IDM table is doing according to the following cases:
  a. The source if it is neighbor.
  b. The destination if it is neighbor.
  c. The intermediate (relay) node if it is neighbor.

3.4.2. Transmission procedure

This procedure can be used in case of low transmission range, where the reduction of power consumption is an important and effective order, and then the probability that the destination is out of transmission area of the source is increased; therefore, the relay node must have the ability of cooperation according to the source signal. The following steps present the transmission procedure in details:

– The source sends RTS to its neighboring nodes (Figure 7 (a)).
– If the destination is within transmission range of the source node, it responds by CTS to start data transmission.
– The relay candidate nodes enter competition if the destination is already in their IDM tables, and PER < ETV for the RTS.
– Each relay node set a timer with an interval (T_i) according to the received signal power (P_s=RTS power), where T_i proportional inversely with P_s; T_i = arg ($1/P_s$). Note that the node with the smallest T_i is the best candidate as a cooperative relay.
– After T_i reaches to zero, the node R_i sends AFR (Figure 7 (b)).
– All neighboring nodes (the other relay nodes, the source and the destination) will receive AFR.
– The other relay nodes will clear their timers, so that only the first node (R_i) with smallest interval will cooperate as a relay node.
– After receiving AFR, the destination sends CTSR (Clear to send with relay) as shown in Figure 7 (c).
– The R_i node forwards CTSR to the transmitter (Figure 7 (d)).
– The transmitter after receiving CTSR, it will send the data with the node R_i as cooperative relay to the destination (Figure 7 (e)).

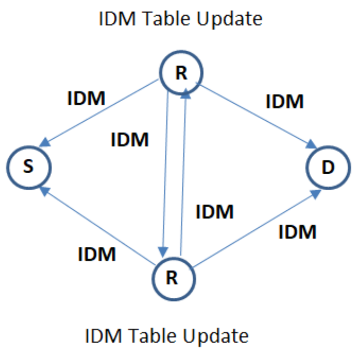

Figure 6. Relay node's IDM table update procedure

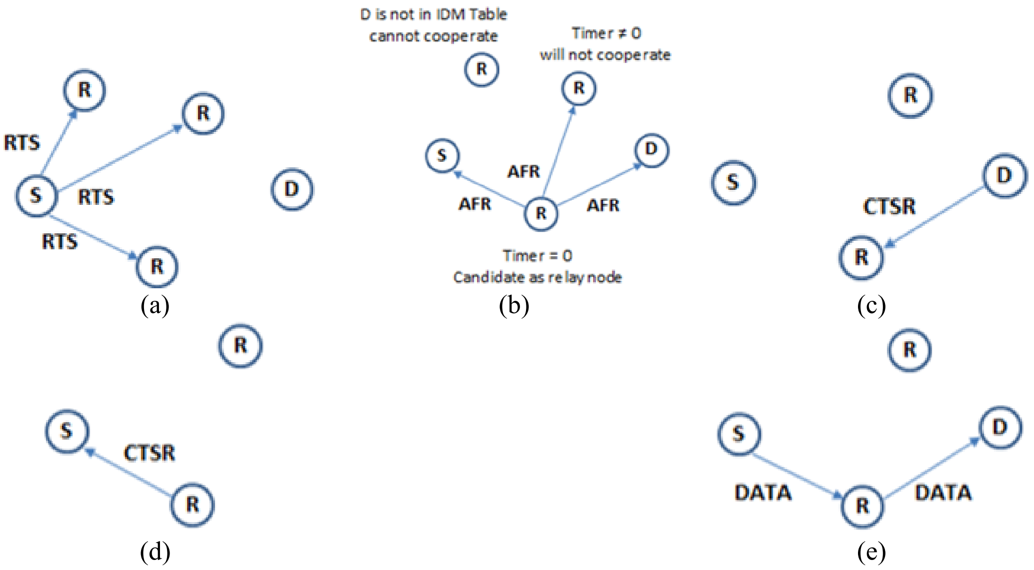

Figure 7. Relay selection with IDM Table–transmission procedure: (a) S sends RTS, (b) Ri sends AFR, (c) D sends CTSR, (d) Ri forwards CTSR to S, and (e) S sends DATA to D

3.5. Relay selection-based relay power consuming

In this scheme, the relay selection process is depended on the amount of relay power consuming per time interval which it will play important role in choosing the best candidate relay node in cooperative wireless network. Then, this proposed protocol can have more enhancements by take power consuming into account. The following two points are summarized this scheme procedure:

– Candidate relay nodes can use their power consuming amounts as metrics in calculate their timer intervals.
– The lower power consuming get lower timer interval, and has more chance in a cooperation process.

4. RESULTS AND DISCUSSION

Performance evaluation of cooperative wireless networks over our proposed relay selection schemes were very useful due to its ease of manipulation and a wide range of compatibility for different wireless networks. Moreover, relay nodes distribution can model different propagation conditions by changing its performance behavior according to our proposed relay selection schemes. In addition, it can provide more enhancement and higher reliability for matching some experimental measurement in comparison with the other relay nodes distributions. On the other hand, conventional relay selection model is famous as a general distribution, where many relay node schemes are modeled. It can be utilized to model relay node selection conditions ranging from severe, light to no selection, by varying its selection parameter.

In order to verify our proposed relay selection schemes, we will consider the following case study to show our proposed schemes robustness and correctness. Let's consider as a case study the relay selection with IDM table scheme to be applying in the cooperative wireless networks shown in Figure 8 which it consists from 10 nodes. The following procedure presents applying our proposed relay selection scheme with this network:

– Node D enters the network, then it sends IDM message as shown in Figure 8 (a).
– Nodes R1, R2, R3 and R4 update their IDM Tables as shown in Figure 8 (b).
– When any node such as S decides to send data to node D, firstly, it sends RTS.
– All nodes with in transmission range will receive RTS.
– D is not in S transmission range.
– Only R2 and R3 will enter competition for cooperation process.
– Each of R2 and R3 set a timer according RTS signal strength. Let R2's timer = 15 μs and R3's timer =10 μs as shown in Figure 8 (c).
– R3 timer fires first, therefore send AFR first.
– After receives AFR, R2 clear its timer, then D knows that there is transmission to it, as in Figure 8 (d).
– D sends CTSR, then R3 forewords CTSR to S as shown in Figure 8 (e).
– S starts DATA transmission to S via R3 as shown in Figure 8 (f).

Based on our proposed relay selection schemes that discussed in previous section, we examine their performances analysis at wireless cooperative networks. Our performance analysis shows that the cooperative relay selection schemes try to increase transmission throughput, energy saving (efficiency maximization), blocking reduction and outage reduction (PER minimization). Table 1 shows the performance evaluation of our proposed relay selection schemes against different performance metrics. Although this supposed table can form a good view about different relay selection approaches, it also provide a good incentive to apply cooperative relay techniques, the effect on overall network performance, that is, the probability of resource blocking, needs further analysis. The problem of transmitting blocking by relays is analyzed through conflict-based relay selection approaches.

Table 1. Performance evaluation of proposed relay selection schemes

Approach	Transmission Throughput Increase	Energy Efficiency Increase	Outage Reduction	Blocking Reduction
Conventional relay selection	-	-	-	-
Relay selection-based destination feedback	-	-	Yes	Yes
Relay selection based RTS/CTS messages	-	Yes	Yes	Yes
Relay selection-based IDM Table	Yes	Yes	Yes	Yes
Relay selection-based relay power consuming	-	Yes	Yes	Yes

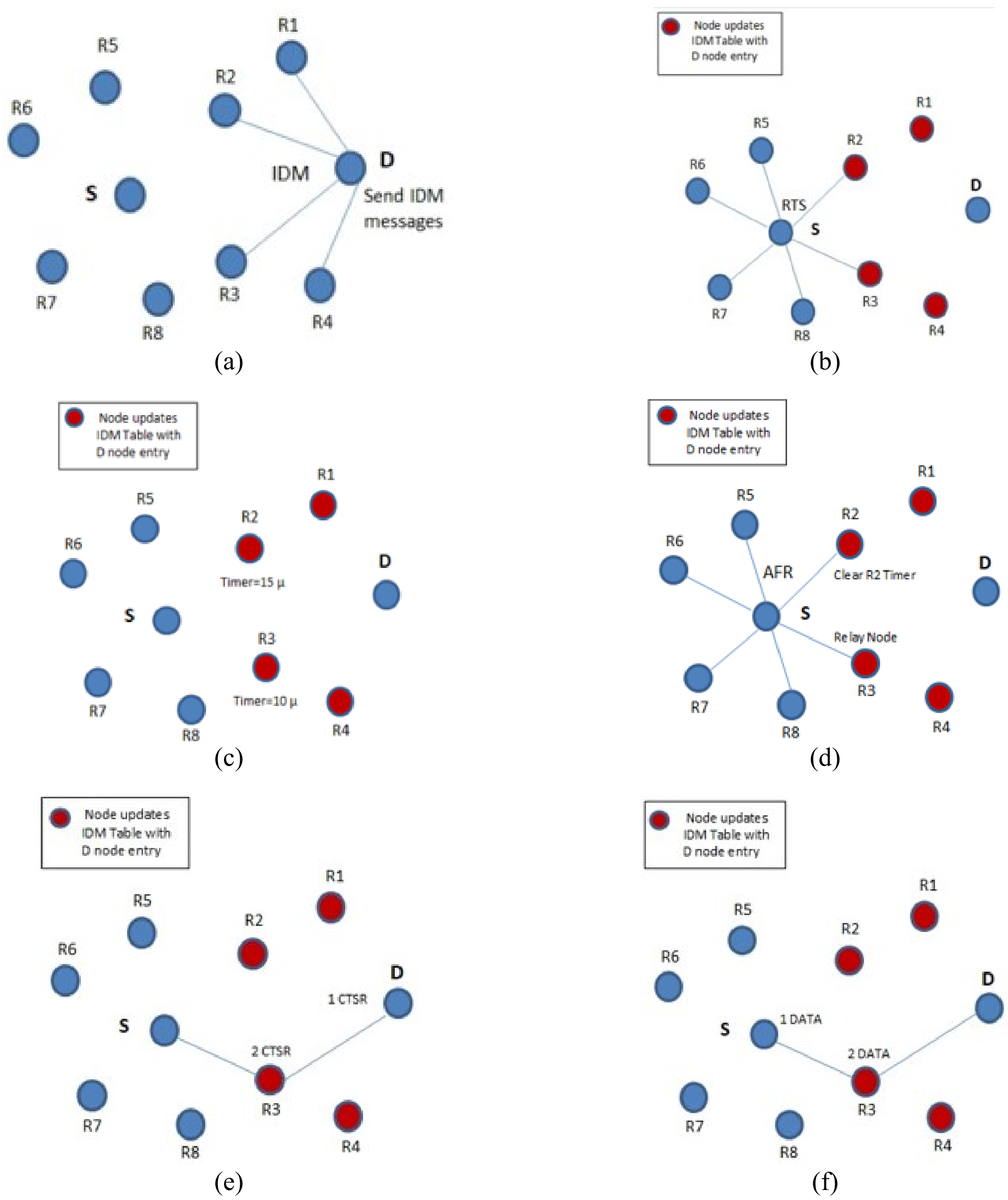

Figure 8. Case study–relay selection with IDM table scheme: (a) D sends its IDM messages, (b) nodes update its IDM tables, (c) R3 & R2 set its timers, (d) R3 clears its timer after receiving AFR, (e) D sends CTSR and R3 forward it to S, and (f) S sends DATA to D via R3

5 CONCLUSION

Relay selection schemes can perform better over networks utilizing a resource optimization scheme. Nevertheless, these strategies are not mutually exclusive and can be used together in a network. Compared to relay selection (RS) and resource allocation, amplifier and forward (AF) mode had been submitted through quite different features and capabilities. Amplifier and forward (AF) mode allows consecutive transmission in multiple relay networks without producing interference and hence can decrease the total power use in the network. A relay subset selection strategy is also discussed showing that relay subset selection enables significant reduction in feedback signaling overhead at an expense of little loss in performance. Derived results show that the diversity gains of best relay selection and partial relay selection are independent of the type of noise, but their SNR gains do depending on the type of noise. Then,the performances of all relays which are grouping in cooperative networks at wireless network system are achieved as well as choosing of the best relay.

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