Performance Analysis of Cooperative Wireless LAN Hybrid Relaying Protocol

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***Abstract* - In recent years the demand for higher data rates in wireless networks is increased rapidly. Due to mobility of devices in wireless networks, the performance has degraded. The cooperative communication performance and reliability can be increased with multipath propagation and low data rate stations. The unstable cooperative procedures cause overhead that will reduce performance. In this paper we analyse the performance with the combination of opportunistic and broadcast based relying approaches. The transmission capacity of wireless networks will be increased with the rectification of draw backs of proactive approaches by introducing broadcast based reactive approaches. The cooperative transmission failures can be recovered using these approaches.**

Key Words: Cooperative diversity, MAC protocols, Hybrid relay, frame error rate, cooperative communication,

I. INTRODUCTION (*Heading 1*)

The Cooperative communications in wireless environments takes advantage of the broadcasting nature and shown better performance in both theoretical analysis and practical [1]. The physical layer requires extra computations as well as synchronizations in cooperative communication. Moreover the MAC layer has performance gain even without aforementioned capabilities [3],[4]. The communication is assisted by transmitting different copies of signals from different locations, generating special diversity. So the different faded signals will be combined at the destination to get error free signal[2]. How to cooperate, whom to cooperate and when to use is provided by MAC layer.

The answer to the above mentioned questions, the authors have proposed cooperative relaying framework, RelaySpot [3], [5]. It has three basic components: cooperative relay scheduling (proactive broadcast behaviour), opportunistic relay selection (proactive opportunistic behaviour) and relay switching (reactive behaviour). The Hybrid relaying approach can perform better than broadcast-based relaying and opportunistic approaches to mitigate the problems posed by the presence of low data-rate nodes and by fading[6],[7]. After overhearing a better frame from the source, the relays are self-elected for a source-destination pair if defined within a cooperation area.

The best set of relays are selected by Access Points (APs) or destination nodes based on the predefined reception window information available at initial stage. The AP will select one only one relay during experimental evaluation. Our hybrid protocol simulation results show that standard 802.11 networks are able to offer throughput, ubiquitous high data-rate coverage with reduced latencies.

This paper continues as follows. Part II presents the Literature survey. In part III we provide hybrid cooperative relaying approaches. In part IV shows the performance evaluation of RelaySpot as example, Part V presents conclusions.

II. RELATED WORK

The cooperation process[8] is proposed as i) discovery and request, ii) negotiation, iii) transaction, and iv) evaluation and feedback. The four phases refers as follows the first phase is cooperation initiation, negotiation to conditions, transaction to rewards and while last phase to quality of experience. The MAC layer consists of two phases: relay selection phase and cooperation phase. MAC layer relaying protocols can either be proactive or reactive, as shown in Figure 1. In proactive relaying data-rate is improved by replacing fast dual-hop relayed communication with slow direct communication potential relay. In case of reactive relaying, to avoid retransmissions relays forward data to the destination when the direct communication fails. CoopMAC is an examples of proactive source-based cooperative relaying schemes which uses table of Channel State Information (CSI). Relay enabled DCF (rDCF) protocol is an example of proactive destination-based relaying schemes. The willingness list is maintained by rDCF relays source-destination pairs that a relay can help. The solution to the overheads in mobile scenarios like channel estimation and periodic broadcasts by maintaining an additional infinite queue to store the frames to be relayed. Opportunistic Relay Protocol (ORP) does not rely on broadcast approach. All the relays try to forward the frame made available by source within the time constraint. During forward the relays back-off every time. The availability of source-relay, the rate of the source-relay and relay-destination channels is not known to source.

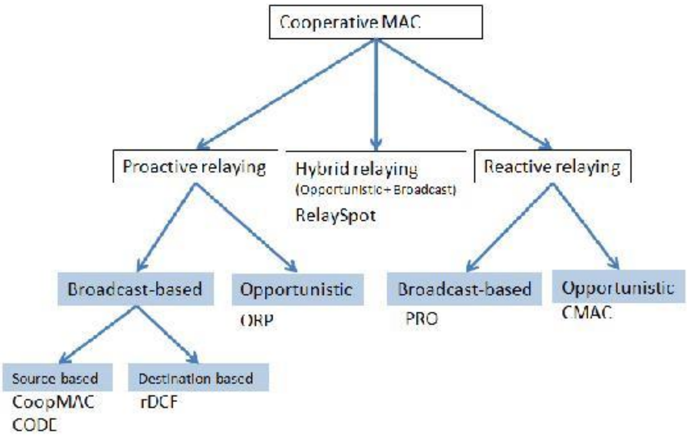

Figure 1. Cooperative MAC Taxonomy

Depending on individual protocols both proactive broadcast-based and opportunistic approaches have pros and cons respectively. The poor relay selection or relay failure issues are not addressed. In Hybrid approach the relays are elected opportunistically based on local parameters while one or more potential candidates is organised by source or destination.

The proactive relaying is considered more compared to reactive approaches because of its advantage to replace the poor links while the reactive approach is for failed data frames. The reaction to failed transaction is achieved by combining proactive and reactive approaches.
The hybrid approaches has the following advantages: it can rectify the poor relay selections; it reacts fast channel variations with the selection fo local relay; and it can react to direct link failures. The broadcast approaches constructs centralized global map for broadcast approach. The opportunistic approaches follow the distributed relaying which causes collisions, poor selection and failed attempts. The overhead is reduced in hybrid approach by combining broadcast-based behaviour into opportunistic one and results to select relay with minimum coordination.
The advantages of hybrid relaying are not clear for a large network capacity. Hence, this paper aims to investigate RelaySpot with broadcast-based and opportunistic mechanisms with a combination proactive broadcast-based and opportunistic relaying is better or not.

III. HYBRID COOPERATIVE RELAYING

As quoted earlier, RelaySpot is an example of hybrid cooperative protocol: it can rectify the poor relay selections; it reacts fast channel variations with the selection fo local relay; and it can react to direct link failures. The RelaySpot is explained in this section:

A. Proactive Operation

Figure 2. a poor direct link between source and destination in RelaySpot operation. The destination sends Cooperative CTS towards source when it observes poor data rate. The self-electing relays chooses best relay or set of relays based on the information sent by potential relays (cooperative relay scheduling). If there is a poor direct link between source and destination, the destination piggybacks the source-destination data rate (Rsd), after receiving a Request To Send (RTS) from source in CTS frame. The relaying initiation is an implicit indication with the insertion of Rsd. The source sends the data frame to destination after the reception of CTS, which start opportunistic relay selection process by potential relays. The ACK frame will not be sent immediately by destination to the source even after the reception of frame. Potential relays waits for some period of time to transmit a Qualification Message (QM) to the destination. Piggybacking the ID of the selected relay or set of relays sent by destination to source after expiration of reception window, the source can infer about the source-relay data-rate (Rsr) by overhearing the QM sent to destination, as well as information about the relay-destination data-rate (Rrd) by potential relays.

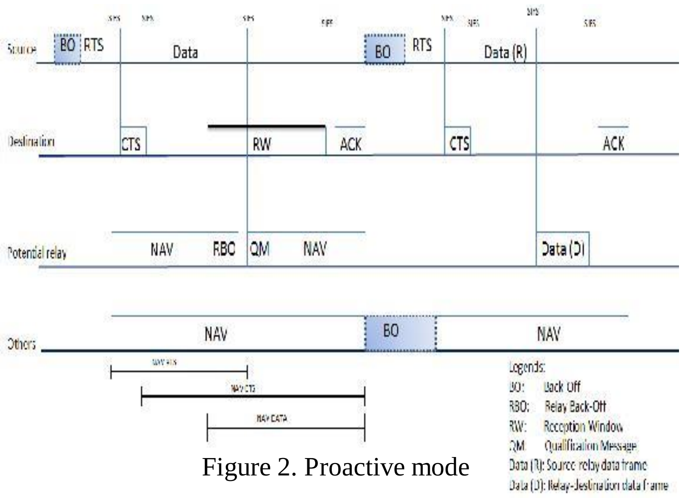

Figure 2. Proactive mode

The cooperative transmission starts by source and relays data frames through selected relay with data-rates Rsr and Rrd. This procedure is repeated until the destination send an ACK without relay ID and Rrd to improve the quality of the direct link.

1) Opportunistic Relay Selection: Cooperation Factor (CF) is computed using equation 1 by relays after verifying they are inside the cooperative area. By overhearing the exchanged RTS and CTS frames the above rates are calculated between source and destination. The potential relays are ensured by closely bounded with source having good channel towards the destination. The CF ensures higher Rsd and Rrd data rate over direct link between source and destination. The contention window is computed by a node which is self-elected to operate as relay it intern relies on the degree of node and traffic load to compute its overall interference. The successful transmission probability is increased by giving more priority to relays which are closely bounded to the destination. Once contention window expires, the QM will send by relay itself to the destination.

CF = (Rsr * Rrd) / (Rsr + Rrd), CF $\in [0, \infty]$ – (1)

2) Cooperative Relay Scheduling:
The destination estimates suitable subsequent transmissions from that source is selected after reception of qualification messages from all self-elected relays. A predefined time

window (Reception Window) processes qualification messages which it has received in multiple. The destination windows decide the size of the reception windows based on the number of qualification messages that will be considered. The QM of the destination will processes all its received qualification messages based on received signal strength Rsd and Rrd after the expiration of reception window.

The source will receive ACK frame from destination by the selected relay, so that it can continue sending received frames to the destination. The destination sends a normal ACK if no QM is received by source. During the relay selection phase the delay is introduced by cooperative relay scheduling and further data frames are relayed via selected relay without contention and much delay.

B. Reactive Operation

The relays in RelaySpot forward data frames if the direct link between source and destination fails on behalf of the source. The overheard data frame will be sent on behalf of source if a node detects failed direct transmission due to collisions or interference to avoid retransmission.

Firstly the self-elected relays are selected by selection process and scheduling their CW for transmission to the destination. The overheard data frame is forwarded by relay whose CW expires first. In comparison to the proactive mode, the relay sends the data frame directly to the destination and does not send a QM in the reactive mode. The source stops the retransmission process Upon overhearing the relay-destination transmission. The potential relay transmits the failed data first as it gets channel since we are not using any QM or scheduler. The relays drop the frame because the source will first retransmit as soon as it gets channel. So, the destination will not receive the data frame as shown in figure 3.

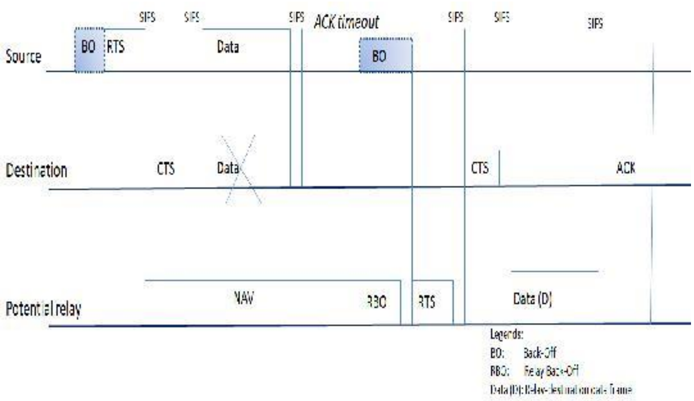

Figure 3. Reactive mode

1) Relay Switching:

The relay switching functionality aims to compensate for unsuccessful relay transmissions and RelaySpot aims to react to a failure of the direct link. It is difficult to find a best relay among several potential relays and faces optimization problem in selection process. The relay spot allows destination to select best possible relay. RelaySpot allows to maintain good quality level by cooperating for replacing current one with in the subsequent data frames by switching the relays. The switching message SM will be sent to destination to provide better performance in the potential relay is not selected in the relay selection process. So, the switching to newly selected relay, since: i) the source will send the next data frame towards the new relay by overhearing the SM frame; ii) After receiving the SM frame the destination knows that the next data frame will arrive through new relay. The selected relay may not be suitable at all stages due to fading, mobility or obstacles. So, relay switching is suitable for dynamic scenarios. The cooperative relaying is best suited for dynamic networks and can overcome variations in network conditions for better performance. Relay switching is best suited for relaying data in failed direct link. If a potential relay retransmits the failed data frame if it detects the cooperative transmission via a relay failed.

IV. PERFORMANCE ANALYSIS

This section provides comparisons with opportunistic and broadcast-based approaches and analyzes the RelaySpot hybrid protocol with some preparatory analysis.

A. Benchmarks

As mentioned earlier, to improve the network capacity the hybrid approaches are not better than broadcast-based and proactive opportunistic approaches. So, we implement a broadcast-based and generic proactive opportunistic relying based on the analysis made earlier. The two fast bit-rate transmissions by reserving channel to transmit the data frames at fast bit rates by sender. The data frame will be forwarded to the destination for 300 μs after performing a back-off by overhearing nodes. The source does not know about the availability of relays and it is called a purely opportunistic behaviour. For every frame to be relayed the same process is repeated.

Table I
SIMULATION PARAMETERS

Parameter	Values
Playground Size	200x200m2
Path Loss Coefficient	4
Carrier Frequency	2.412e9 Hz
Max Transmission Power	100 mW
Signal Attenuation Threshold	-120 dBm
MAC Header Length	272 bits
MAC Queue Length	14 frames
Basic Bitrate	1 Mbps
Rts-Cts Threshold	400 bytes
Thermal Noise	-110 dBm
MAC Neighborhood Max Age	100 s
Payload Size	1 K bytes

The generic broadcast-based approach is implemented by considering the proactive source-based mechanism. Based on passive overhearing, the source selects relay prior to transmission after updating a cooperative table. The address 4 of RTS frame has relay address for initiating a transmission.

The cooperative transmission starts after relay sends control frame of type CTS from destination to source.

B. Simulation Setup

The simulation parameters are tabulated in the table and evaluated using NS2 simulator. Each simulation run ten different times for about 300 seconds to get 95% better results in the static scenario. This paper proposes a WLAN consisting of 25 nodes connected to 1 AP distributed randomly. Each node is allocated a unique MAC address and a half duplex link. The control frames and data frames are transmitted among nodes using same power. The wireless access point is shared among all nodes and frames are transmitted across it. The control frames are being transmitted at the basic rate and depending on the distance of AP and nodes the data rates are determined.

C. Preparatory Analysis

The hybrid approaches performance is significant due to reception window impact. The simulations are performed with a network load of 10K fps using relay selection with scheduler. The results shown in fig 4 show that the size of reception window is as big in order to accommodate larger number of QMs by AP for selecting the best relay with high probability.

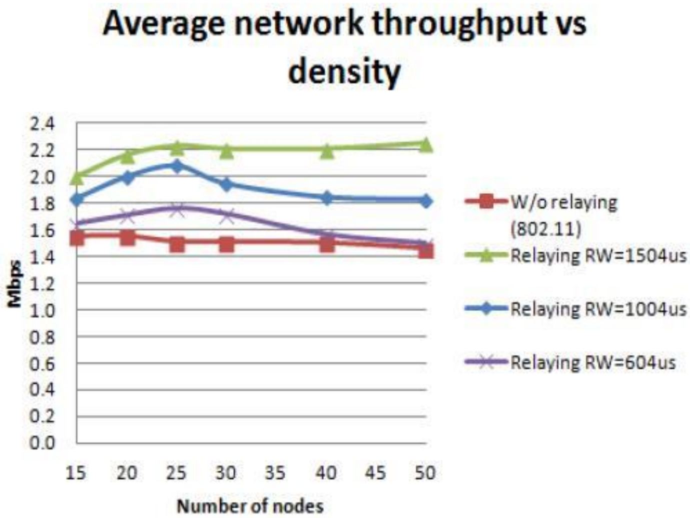

Figure 4. Analysis of impact of reception window

The transmission of QM takes 304 us at the basic bitrate with a size of 112 bits. As shown in figure 4 the destination has only one relay because the small reception window (604 us) selects only one QM. The source selects a relay with high probability nodes closer to it and overhears the good copies of source frames. The destination is not able to finalize a relay due to collision of QMs which leads to low throughput even with higher node density. The reception window size has good impact on throughput gain. Our estimation of 1504 us size of reception window gain 44% of throughput when compared to the direct link. Our results show that throughput gain increases with a bigger reception window as expected. The larger window reception introduces delay and it impacts during relay selection only but not during the process of data relaying. So optimally we select the size of reception window to 1504 us.

D. Impact of Interference

The impact of the cooperative relay scheduling can be studied in which relays are subjected to interference with a set of simulations. Hybrid approaches like RelaySpot have better performance than IEEE 802.11 in the presence of interference as shown in Figure 5. RelaySpot select relays with low blockage probabilities which avoids selecting overloaded nodes as relays for higher number of transmission possibilities. Consider a case with poor data rate by placing one source at a distance from AP and adding interference among available 25 nodes by randomly placing transmission pairs.

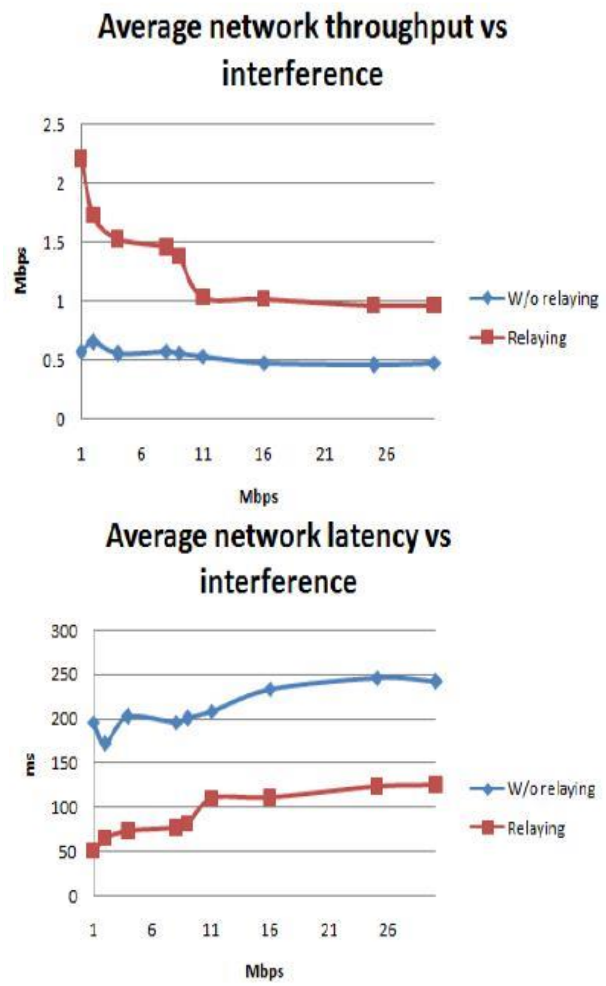

Figure 5. Analysis of impact of interference

The gain in throughput and latency drops linearly with the introduction of interference for the source. Whereas high throughput is achieved by RelaySpot with a capability to have better success rate of transmission towards destination. These relays are within the cooperative area as specified in the equation 1. The average latency is gained by 148% compared to 802.11 because of its ability to select maximum number of higher successful transmission opportunities for the relay with low load of concurrent nearest flows. The relays has lower latency and less blockage. the gain in both throughput and latency will be stabilized at 25Mbps interference level as shown in figure 5. We can achieve better results without using scheduler in RelaySpot [7], [6], and gain is stabilized at an interference level of 60Mbps. The relay selection mechanisms ensure a good performance with high interference among the qualified relays. Among the qualified relays the scheduler at the destination is able to choose a relay with better rate and relays with less blockage probability.

E. Comparisons

We compare the approaches of opportunistic and broadcast based implementation with hybrid approach called RelaySpot with scheduler and switching functionality. The set up for simulation as mentioned in Section IV-C.

Relay failures can be minimized by using relay switching functionality in hybrid approach has more advantages as shown in figure. 6. The throughput gain is of 63% when compared to 802.11 using a relay switching functionality with an increase in 19% as compared to RelaySpot without switching.

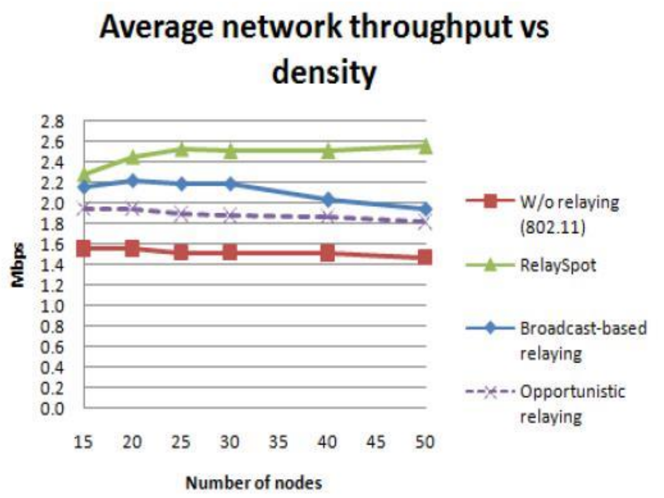

Figure 6. RelaySpot Analysis

The multiple relays has overhead because one relay is selected each time as compared to other relays which cooperate as and when its required [16]. It is not limited to choose a specific set of relays among multiple relays. Due to avoiding relay re-selection and changing relays will reduce overall contention by the better opportunistic node.

We can estimate our contribution to good network capacity with a relays on scheduling and switching. We compare the results of proactive broadcast-based and opportunistic relaying with proposed hybrid approach. to guaranty correct channel reservations The broadcast-based relaying uses extra messages to avoid collisions. So the gain of 40% in the throughput is achieved when compared to IEEE 802.11. However, if the network density increases, the relay failure increases due to collisions which intern decreases the gain. Both Hybrid and broadcast-based approaches have better gain when compared to opportunistic-based relaying. Figure 6 clearly shows the gain of throughput by 24% by opportunistic relaying when compared to IEEE 802.11. The performance gain is reduced because the availability of relays was not known to source or destination, collisions and failed relay attempt. Therefore, we conclude that a good cooperative relaying approach (e.g RelaySpot) will increase network performance by decreasing the relaying overhead impact.

V. CONCLUSIONS

In this paper, we have analysed RelaySpot, a hybrid relaying protocol. The performance of wireless networks has improved using this protocol an efficient combination of proactive and reactive relaying. In cooperative transmission the relay is chosen opportunistically but not with broadcast overhead by RelaySpot. The relay does not maintain table for cooperative transmission and takes place without contention. The relay selection procedure adjusts relay failures and poor relay selections dynamically. Finally, we conclude that the disadvantages of broadcast-based and opportunistic relaying has rectified by hybrid behaviour.

Our simulation results shows that an average throughput gain of 33% and 19% by a proposed hybrid relaying compared to proactive opportunistic and broadcast-based relaying respectively (under experimental conditions with varying density for a network load of 10K fps). The hybrid relaying with the presence of interference also increases WLAN transmission capacity. So, the RelaySpot achieves higher gain in comparison without scheduling algorithms [7],[8].

In future work the synchronization of nearby cooperative relays for achieving higher wireless density than the one we achieved. The scenario of selecting more than one relay by the destination will achieve better wireless diversity.

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