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Opportunistic Cooperative Retransmission Enhancements for the IEEE 802.11 Wireless MAC

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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LIST OF ALGORITHMS

LIST OF ABBREVIATIONS

AaF	Amplify and Forward
ACK	ACKnowledgement (MAC layer frame)
ARQ	Automatic Repeat reQuest
BO	Back Off
CBR	Constant Bit Rate
CDMA	Code Division Multiple Access
CFC	Call For Cooperation (custom MAC layer frame)
CSI	Channel State Information
CSMA/CA	Carrier Sense Multiple Access - Collision Avoidance
CTS	Clear To Send (MAC layer frame)
DaF	Decode and Forward
DAFMAC	Decode And Forward MAC (protocol)
DCF	Distributed Coordination Function
FDD	Frequency Division Duplexing
FDMA	Frequency Division Multiple Access
FCS	Frame Check Sequence
i.i.d.	independent and identically distributed
MAC	Medium Access Controller
MIMO	Multiple-Input Multiple-Output
MRC	Maximal Ratio Combining
NAK	Negative AcKnowledgement
PRO	Protocol for Retransmitting Opportunistically (MAC protocol)
QoS	Quality of Service
RTS	Request To Send (MAC layer frame)
TDMA	Time Division Multiple Access

LIST OF PARAMETERS

$d_{a,b}$	distance between points a and b
N_b	the *best* relay node as identified using the relay selection algorithm
N_d	the destination node
N_i	the ith node, used to refer to any node
N_s	the source node
$\mathcal{N}_c$	the set of relays contending for retransmission, $\mathcal{N}_c \subseteq \mathcal{N}_p$
$\mathcal{N}_n$	the total set of nodes that are neighbours to both N_s and N_d
$\mathcal{N}_p$	the set of relays participating in the retransmission process, $\mathcal{N}_p \subseteq \mathcal{N}_n$
ρ_n	(average) number of neighbours of each node
$RSS_{a,b}$	received signal strength at node N_b for transmission sent by node N_a, typically represented in dBm
SNR_{off}	minimum link quality offset (used only in proof of concept relay selection algorithm)
SNR_{rng}	range of expected SNR values between the lowest and highest path loss
t_i	contention delay generated by node N_i
T_{difs}	distributed inter-frame space
T_{phy}	duration of physical layer training sequence
T_{sifs}	short inter-frame space
T_{slot}	slot time for the MAC CSMA/CA back off sequence

ABSTRACT

Cooperative retransmission protocols improve wireless transmission reliability by providing distributed channel diversity. Unfortunately, this diversity comes at the cost of increased protocol complexity and processing overhead, which limits the scalability of cooperative protocols in large networks.

This Thesis introduces DAFMAC, an opportunistic retransmission protocol which operates without any explicit control messaging. DAFMAC uses passive transmission observations to select a suitable opportunistic relay using a distributed algorithm. The immediate benefit of reducing overhead is to enable a greater proportion of channel time available for data transmissions. The DAFMAC retransmission algorithm is compared to contemporary protocols through extensive simulations to evaluate network performance. The key result is that DAFMAC is able to meet or exceed the performance improvements of “coordinated” retransmission algorithms such as PRO and Δ-MAC, for metrics which include total network throughput, individual link fairness, energy efficiency, end-to-end transmission time and jitter. A proof-of-concept implementation of DAFMAC was deployed in a physical test-bed and was shown to significantly improve throughput in high path-loss links.

This Thesis also derives a general retransmission model which is applicable to many distributed cooperative algorithms. Due to the complexity of implementing cooperative protocols in simulators, algorithms are typically only compared to traditional non-cooperative ARQ retransmissions. Further, analytic models typically include naïve simplifications that makes meaningful comparisons between algorithms impossible. The analytic model presented in this Thesis calculates the opportunistic retransmission outcome probability and includes detailed failure-mode results which may be used to rapidly compare algorithm performance with different configuration parameters in addition to comparing different protocols. Using the straightforward design principles of a retrans-

mission algorithm, the model is able to accurately reproduce the cooperative performance results of a full state-based simulation. The retransmission model is independent of the channel model to facilitate performance analysis in different scenarios.

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