Random Access Schemes for Multichannel Communication and Multipacket Reception in Wireless Networks

by

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Abstract

Random access schemes have used advanced capabilities of the physical layer to achieve reliable data transmissions over wireless communication channels. These capabilities include *multichannel communication* and *multipacket reception*. Incorporating the advanced capabilities into the access schemes, as a cross-layer design, is a challenging task because a more sophisticated approach is required to interface the physical layer and the medium access control (MAC) layer.

This thesis presents development of research into the efficient random access schemes that provide a better set of cross-layer design approaches by taking into account the capabilities of multichannel communication and multipacket reception. The consideration is to propose multichannel random access schemes that use a channel outage concept of fading and interference. The system performance of the proposed schemes is then analysed. By considering imperfect channel information, a random backoff access scheme that operates with a channel sensing policy is developed. The sensing and access problem is formulated as a partially observable Markov decision process, and is solved with simple and efficient heuristic approaches. A new joint random access scheme that resolves packet collisions in the time and frequency domains is then proposed to enable effective uplink access. The joint scheme cooperates with a sensing method in which users are partially aware of channel conditions. With multipacket reception (MPR) capability, a new MAC protocol is developed by adopting a distributed access mechanism to support a wireless network in which MPR capable nodes coexist with non-MPR nodes.

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Statement of Originality

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List of Abbreviations

PHY	Physical Layer
MAC	Medium Access Control
MPR	Multipacket Reception
FDM	Frequency Division Multiplexing
OFDM	Orthogonal Frequency Division Multiplexing
SIMO	Single Input Multiple Output
MIMO	Multiple Input Multiple Output
RTS/CTS	Request-To-Send/Clear-To-Send
LOS	Line of Sight
TDMA	Time Division Multiple Access
CDMA	Code Division Multiple Access
FDMA	Frequency Division Multiple Access
OFDMA	Orthogonal Frequency Division Multiple Access
UL-MAP	Uplink Map
PRMA	Packet Reservation Multiple Access
CSMA/CA	Carrier Sense Multiple Access with Collision Avoidance
QoS	Quality of Service
SNR	Signal to Noise Ratio
WLAN	Wireless Local Area Network
CSI	Channel State Information

LTE	Long Term Evolution
GSM	Global System for Mobile Communications Protocol
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide Interoperability for Microwave Access
POMDP	Partially Observable Markov Decision Process
NAV	Network Allocation Vector
SIFS	Short Interframe Space
DIFS	Distributed Interframe Space
ACK	Acknowledge
NUM	Network Utility Maximisation
BPSK	Binary Phase Shift Key
QPSK	Quadrature Phase Shift Key
QAM	Quadrature Amplitude Modulation

List of Symbols

K	Number of users
N	Number of channels
$q_{n,i}$	Channel outage probability of user i over channel n
$p_{n,i}$	transmission probability of user i over channel n
p^{max}	Maximum transmission probability
p_c	Conditional collision probability
β	A reducing factor
S	System throughput
G	Offered channel traffic
τ	Stationary transmission probability
$P_{i,j}$	One-step transition probability from state i to state j
$P(i,j\|m,h)$	One-step transition probability from state $\{m,h\}$ to state $\{i,j\}$
π	Stationary probability of staying at state i
$\pi_{i,j}$	Stationary probability of staying at state $\{i,j\}$
$S(t)$	Network state at slot t
$A(t)$	Action state at slot t
$r(S(t),A(t))$	Reward function of $S(t)$ and $A(t)$ at slot t
$\Lambda(t)$	A belief vector at slot t
$V_t(\Lambda(t))$	Maximum expected remaining reward at slot t
$\Omega_i(t)$	Probability distribution of user i's channel conditions at slot t

p_t^d	Packet transmission probability of direct-links
p_t^u	Packet transmission probability of up-links
P_{tr}	Probability that there is at least one packet transmission among all users
P_s^u	Conditional probability that multiple up-links are successfully established
P_s^d	Conditional probability that multiple direct-links are successfully established
P_{idle}	Probability of an idle transmission
P_{coll}	Probability of a collision
P_{succ}	Probability of a successful transmission
T_s	Time duration for a successful transmission
T_c	Time duration for a collision
W^d	Contention window size for direct-links
W^u	Contention window size for up-links
S_{opt}	Optimal throughput
S_{max}	Maximum throughput

List of Publications

1. H. Lee, I. Oh, and J. Choi, "An energy and traffic aware clustering (ETC) algorithm for wireless sensor networks," in *Proc. Performance Control in Wireless Sensor Networks (A Workshop at the 2006 IFIP Networking Conference)*, Coimbra, Portugal, May 15-19, 2006, vol. 1, pp. 46-53.

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7. H. Lee, C.C. Lim, and J. Choi, "Joint backoff control in time and frequency for multichannel wireless networks and its Markov model for analysis," accepted, Discrete and Continuous Dynamical Systems - Series B, 6 May 2011.

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