Poster: Efficient Power Control Based on Interference Range in Wireless Ad Hoc Networks

Junmei Yao*,†, Wei Lou*,† and Chao Yang*,†
*Department of Computing, The Kong Polytechnic University, Kowloon, Hong Kong
†The Hong Kong Polytechnic University Shenzhen Research Institute, Shenzhen, P. R. China
Email: {csjyao, csweilou, cschaoyang}@comp.polyu.edu.hk

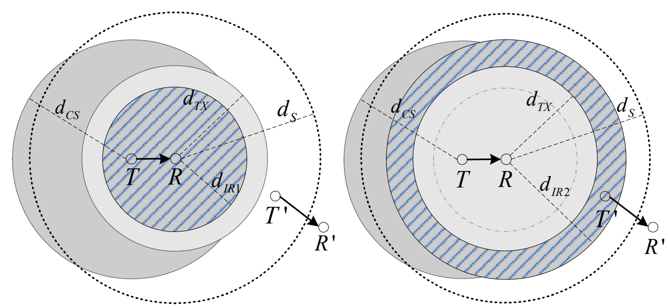
Abstract

Energy management through power control in wireless ad hoc networks has a serious hidden terminal problem called POINT, which is caused by the varied interference range induced by the controlled transmission power. Current researches that solve the POINT problem are inefficient as they either increase the energy consumption, or degrade the network performance through prohibiting effective data transmissions or leading to collisions in some scenarios. This work presents IRPC, a novel protocol to solve the POINT problem completely. IRPC makes the data packet transmitted at the required minimum power. Meanwhile, it makes the interference range of each link covered by the CTS transmission but without increasing CTS's transmission power, through utilizing a signature detection method. It also makes CTS carry the information of interference range, according to which other nodes can determine whether they are outside the interference range of the ongoing link and can initiate data transmissions, so as to permit effective transmissions and avoid collisions.

1 Introduction

As nodes are always battery-powered in wireless ad hoc networks, it is a critical issue to manage the energy consumption efficiently to increase the network lifetime. Power control is a well-known method to decrease the nodes' energy consumption through decreasing the transmission power to a designed value. Designing power control mechanisms has attracted much research interest recently.

The basic power control mechanism [1] makes use of RTS/CTS exchanges: RTS and CTS are transmitted at the maximum power P_{max}, while data and ACK are transmitted at the necessary minimum power P_{min}, which just makes the received data packet's SINR value above a threshold. This mechanism suffers from a serious POINT (power control induced hidden terminal) problem, as the interference range d_{IR} of one link $T \to R$ changes with the data transmission power P_{min}. When P_{min} decreases, d_{IR} is enlarged. As a result, one node that is originally outside d_{IR} of the link becomes locating inside d_{IR} of this link, and will interfere with this link's data transmission.



(a) $P_t = P_{t1}$ (b) $P_t = P_{t2}$

Figure 1. The POINT problem and the concept of IRPC protocol.

Some researchers propose to improve the power control mechanisms to combat the POINT problem, such as predicting collisions and preventing them [2], increasing the transmission power of CTS to make its transmission range larger than d_{IR} [3], and so on. These schemes either do not solve the POINT problem effectively, or prohibit some effective data transmissions. Recently, an ARPC protocol [4] is proposed to combat this problem through making the interference range of one link within the maximum coverage of both the data's carrier sense range and the CTS's transmission range. However, the required data transmission power in this protocol is much larger than P_{min}, thus results in a higher energy consumption. Meanwhile, it still cannot solve the POINT problem efficiently when the packet size is large and transmitter-receiver distance is long.

In this work, we will propose a novel Interference-Range-based Power Control (IRPC) protocol to minimize the data transmission power, avoid collisions and increase concurrent transmissions, so as to improve the network performance.

2 IRPC Design

The Overview of IRPC The basic idea of IRPC is to let the interference range d_{IR} of the ongoing link always covered by the CTS transmission but without increasing the CTS transmission power. We propose to accomplish it through

International Conference on Embedded Wireless Systems and Networks (EWSN) 2016
15–17 February, Graz, Austria

ISBN: 978-0-9949886-0-7

Preamble	FC	NAV	RA	P_{min}	CRC	IR(S)	NAV(S)

PHY Layer MAC Layer

Figure 2. The CTS frame format.

utilizing a signature detection method in the physical layer, which has already been used in [5] to detect known signals under low SINR environments. As the signature's detection range d_S is large enough to cover d_{IR} in all situations, IRPC can combat the POINT problem effectively. As shown in Figure 1, the POINT problem occurs when the data transmission power P_t changes from P_{t1} to P_{t2}, the node T' that is outside d_{IR} in Figure 1(a) becomes within d_{IR} in Figure 1(b). However, IRPC can combat this problem as T' is within d_S and can detect CTS correctly to keep silence. Meanwhile, as d_S can cover d_{IR} in all cases, T can always use P_{min} to transmit data packets.

Besides avoiding interference, another concern in the power control mechanism is to enable concurrent transmissions to increase the network throughput. As shown in Figure 1(b), T' should be prohibited to transmit packets when the interference range is d_{IR2}. However, in the case of d_{IR1} in Figure 1(a), it can have the opportunity to transmit packets as its transmission will not interfere with the ongoing link $T \to R$. In this paper, we make CTS carry the information of the interference range, so that the neighboring nodes that receive CTS can figure out whether they are within or outside the interference range of the ongoing link, so as to make proper channel access decisions.

Signature Detection To make CTS detected through the signature detection method[1], we let the CTS message be filled with signatures, which are known bit sequences and designed to carry the control information. After receiving the signatures, one node will detect them by doing cross correlation between each known sequence and the incoming signal. If a high correlation result appears, the known sequence that carries some specific information is determined to be in the incoming signal. This method can detect signatures under very low SINR environments. As the signature detection range d_S is very large, the condition $d_{IR} < d_S$ can be always held in the network.

CTS Message Design We design a new CTS frame for the IRPC protocol to make CTS carry the needed information, and make some information detectable by the signature detection method. As shown in Figure 2, we add three new fields for the standard CTS frame: (1) P_{min} that carries the P_{min} value for the transmitter, (2) *IR(S)* that carries the d_{IR} value of this link for the neighboring nodes, and (3) *NAV(S)* that carries the duration of the data transmission for the neighboring nodes. The P_{min} field is in the MAC layer and will be decoded normally by the transmitter. Both *IR(S)* and *NAV(S)* fields are in the physical layer and filled with signatures, so as to be detected by the neighboring nodes through the signature detection method even when the nodes are out of the transmission range of the CTS transmitter. Here we omit detailed design for the three fields due to page limit.

[1]The details of the signature detection method can be found in [5].

IRPC MAC Process We use Figure 1 as an example to illustrate the procedure of IRPC MAC protocol:

When T intends to transmit data packets to R, the transmission is permitted as there is no ongoing link. It then transmits RTS at power P_{max} to initiate the data transmission. After receiving the RTS successfully, R will first accomplish the new CTS message and then broadcast it at power P_{max}. After detecting CTS successfully, T will begin to transmit the data packet at the power value P_{min} carried in CTS.

For the other nodes around this link, such as T' in Figure 1, it will detect the signatures in the *IR(S)* and *NAV(S)* fields through the signature detection method, then transform them into d_{IR} value and NAV time. Only if it is within d_{IR} of this link, it should update its NAV state. That means, T' should update its NAV state in the case of Figure 1(a), but should not in the case of Figure 1(b).

During the data transmission of $T \to R$, when T' intends to transmit data packets to another node R', it will first check whether its NAV state is zero. If the NAV state is zero, it can transmit a RTS at power P_{max} to initiate the data transmission. Otherwise, it should wait until the end of the transmission $T \to R$.

3 Conclusion

In this work, we propose a new power control protocol named IRPC to combat the POINT problem in wireless ad hoc networks, so as to both improve the network performance and decrease its energy consumption. IRPC makes nodes transmit data packet at the needed minimum power to minimize the energy consumption. Meanwhile, it makes the interference range of one link covered by its CTS transmission, through utilizing a signature detection method. It also makes CTS carry the information of interference range, based on which all the other nodes can make proper decisions to permit effective data transmissions and avoid collisions.

4 Acknowledgement

This work was supported in part by grants from National Natural Science Foundation of China (No. 61272463), Shenzhen's National/Provincial Project Matching Fund (R2013A069), Hong Kong RGC (PolyU-521312), Hong Kong PolyU (4-BCB6, M-N020).

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