A Scheme of Channel Diversity Load Balancing Consideration for Path Selection in WMNs

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요 약

This paper proposes a channel diversity based load-balancing cross-layer routing scheme for Wireless Mesh Networks (WMNs). The proposed scheme deals with channel diversity phase and load balancing phase in WMNs. Channel diversity factor $metric_{ch\text{-}d}$ and load balancing factor f_{load} are defined and employed cooperatively as a combined path selection policy.

1. Introduction

Wireless Mesh Networks (WMNs) is gaining significant attention due to their desirable characteristics such as easy deployment, low cost, wireless infrastructure, compatibility with existing wireless networks, multiple radios, multiple types of network access, mobility, self-healing and self-organization [1]. Wireless Mesh Networks can be seen a s a combination of WMANs, WLANs and Wireless Sen sor Networks [2]. All these characteristics impose additi onal challenges on routing protocols as well as on netw ork configuration for WMNs.

It is suggested that design of routing protocol for WMN s consider the following issues: effect of multiple chann els or channel diversity and channel assignment (CA), a vailability of static mesh router infrastructure backbone, load balancing, selection of routing metrics, effects of g uaranteed quality of service (QoS) and cross layer optim ization [3]. Our work deals with the issues of channel di versity and load balancing. We proposed a channel diver sity based load balancing routing scheme for WMNs in this paper. Section 2 reviews related work. In section 3, our research motivation is described and our scheme is proposed. Finally section 4 concludes the paper.

2. Related Work

Channel-diversity Routing Protocols

A channel aware multipath metric (CAM) is proposed that accounts for both channel diversity between the paths and the end-to-end characteristics of the individual paths by means of weighted average of intra-path metric and inter-path metr ic [4]. A metric of physical-layer properties named interf erence factor is introduced that is related to the channel separation *t* of two links [5]. H. L. Nguyen et al. [8] d eveloped a new channel assignment metric that solves th e interference factor problem by using the channel separ ation that is difference of channel numbers of channel p airs. Metric of Interference and Channel-switching (MIC) is proposed in paper [6].The MIC metric improves *WCE TT* by solving its problems of non-isotonicity and the in ability to capture inter-flow interference. S. Lee et al. pr opose a new routing protocol which is committed to sel ect high throughput paths based on channel information and reduce the broadcast overhead caused by control me ssages [7]. MCMNT attempts to minimize the total num ber of transmissions in a multicast group in MCMR me sh network as its name implies [3].

Load Balancing Routing

Multi-path routing is proposed to perform better load balancing and to provide high fault tolerance. When link is broken on a path due to a bad channel quality or mobility, another path in the set of existing backup paths can be chosen [2].

N. S. Nandiraju et al. propose a multipath hybrid routing protocol Multipath Mesh (MMESH) [9]. The idea of restricting the set of routes for delivering traffic flow from a particular source is derived from the traditional source routing technique. A protocol named Joint Multi-channel and Multi-path control (JMM) is introduced which combines multichannel link layer with multi-path routing [10]. This protocol is able to overcome the bottleneck at intermediate nodes and increase end-to-end throughput by decomposing the traffic over different channels, time and space.

3. Proposed Scheme

For any type of network an effective routing protocol with appropriate path selection metric is desired. The pr oposed scheme deals with channel diversity phase and l oad balancing phase in WMNs. Firstly the path selectio n metric with channel diversity factor is described. Then multi-path selection mechanism is introduced.

I. Path Selection Metric with Channel Diversity Factor

Let's take two-hop paths as example to illustrate our idea. Assume there exist several paths between source node v_s and destination node v_d. We define:

i. $V_{intermediate} = \{ v_1 , v_2 , v_3 \ldots v_i \}$ is the set of the intermediate nodes along *i* paths from v_s to v_d

ii. *ch-n* (v_s , v_i) is the assigned channel number of the link (v_s , v_i) incident to the intermediate node v_i

iii. *ch-n* (v_i , v_d) is the channel number of the link (v_i , v_d) incident from the intermediate node v_i.

iv. $c_i (v_s , v_i , v_d)$ is the cost of a two-hop path from v_s to v_d via the intermediate node v_i.

v. *ch-d* is *channel diversity factor* which is set to *false* state when *ch-n* (v_s , v_i) is equal to *ch-n* (v_i , v_d) and is set to *true* state when *ch-n* (v_s , v_i) is not equal to *ch-n* (v_i , v_d). *Channel diversity factor* indicates the channel diversity condition of a path and the probability of improving the path cost.

When *ch-d* appears *false state*, v_i is unable to transmit and receive data concurrently, thus $c_i (v_s , v_i , v_d) = c (v_s , v_i) + c (v_i , v_d)$.

When *ch-d* appears true state, v_i transmits and receives data concurrently , therefore $c_i (v_s , v_i , v_d) = max \{c (v_s , v_i), c (v_i , v_d)\}. \leq c (v_s , v_i) + c (v_i , v_d)$.

The modified path selection metric with concern for cha nnel diversity takes the path with minimum cost.

$$metric_{ch\text{-}d} = min \{ c_i (v_s , v_i , v_d) \} \qquad (1)$$

II. Multi-path Selection Mechanism Considering Load-balancing

HWMP (Hybrid Wireless Mesh Protocol) works at MAC layer and the architecture of HWMP routing table is composed of the flowing fields: destination MAC address, next hop MAC address, interface index, metric, sequence number and status. In the proactive mode of operation, a single mesh station is configured to be a tree root and it broadcasts *PREQ (Path Request)* packets periodically. Each station receiving a proactive *PREQ* updates its path to root and answers to it by *PREP (Path Reply)*. Due to this process, every station knows the route to tree root and root knows a route to every mesh station. The proposed multi-path selection mechanism works in this proactive tree-based mode.

For a *PREQ/PREP/RANN (Route Announcement)* packet p_m received by a mesh node, we define: *s-v*(p_m), *tr-v*(p_m), *metric*(p_m), *seq-no*(p_m) is originator, current transmitter, metric and sequence number respectively recorded in p_m.

The element fields of an entry en_j in routing table $RT = \{en_1 , en_2 ,\ldots en_j\}$ of a mesh node are defined as *des(e* n_j*)* (the destination MAC address), *next-v*(en_j) (next hop), *metrix*(en_j) (metric), *seq-no*(en_j) (sequence number) and $en_j \in RT$.

Due to broadcasting propagation, *RANN*s reach the root through various paths but only the path with the best m etric is recorded according to HWMP. We modified HW MP. According to our protocol, on receiving *RANN*s coming from root node via each path, the information of each path is recorded in the routing table of local mesh node and multiple paths are established.

Assume two entries en_1 and en_2 sharing the same destin ation (*des*(en_1) = *des*(en_2)) but with different next hop (*next-v*(en_j) ≠ *next-v*(en_j)). The mechanism to distinguish the entry en_1 from en_2 is critical for establishing multipl e paths and the implementing process is described below.

1) Multi-path Establishing Mechanism

Step 1. Root transmits *RANN* packets periodically. When the node receives a *RANN* packet p_1, it retrieves entries in routing table to find out if there exists sets of entries defined as:

$$En_m = \{ en_j \in RT : des(en_j) = s\text{-}v(p_m) \text{ and } next\text{-}v(en_j) = tr\text{-}v(p_m)\} \qquad (2)$$

$$En_{update} = \{ en_k \in En_m : seq\text{-}no(en_k) \leq seq\text{-}no(p_m) \text{ or } metrix\ (en_k) \text{ inferior to } metric(p_m) \} \qquad (3)$$

i. If $En_1 = \varnothing$, insert a new entry en_{j+1} into rou ting table *RT* , let $des(en_{j+1}) = s\text{-}v(p_1)$, $next\text{-}v(en_{j+1}) = tr\text{-}v(p_1)$, $seq\text{-}no(en_{j+1}) = seq\text{-}no(p_1)$, $status(en_{j+1}) =$ *off*.

ii. Else if $En_{update} \neq \varnothing$, update $en_k \in En_{update}$, broadcast p_1 ,unicast p_1 to the originator $s\text{-}v(p_1)$ and send PREQ to the current transmitter $tr\text{-}v(p_1)$.

iii. Else ($En_{update} = \varnothing$), the *RANN* packet p_1 is dis carded.

Step 2. When the root receives *PREQ* p_2, for each entry in *RT*,

i. If $En_2 = \varnothing$, insert a new entry en_{j+1} into *RT* to record the information of p_2 , and let *status* (en_{j+1}) be *on.* Send *PREP* to the current trans mitter $tr\text{-}v(p_2)$ which will deliver it to the origi nator $s\text{-}v(p_2)$.

ii. else ($En_2 \neq \varnothing$), then update $en_k \in En_2$.

iii. send *PREP* to the current transmitter $tr\text{-}v(p_2)$ w hich will deliver it to the originator $s\text{-}v(p_2)$.

Step 3. When mesh node receives *PREP* p_3, find out En_3 and let *status* ($en_j \in En_3$) be on .

Step 4. Since root transmits *RANN* packets periodically, step 1 is repeated.

2) Multi-Path Selection Metric

RTS (*Ready-to-Send)* fail can act as the indicator of link quality measurement. We extend a new field into en_j to record RTS fail ratio which is defined as the ratio of R TS fail count over packet count in a time interval *t* fro m the mesh node to next hop. We define RTS fail ratio as a load balancing factor $f_{load}(en_j)$ which acts as the m etric of link quality. The proposed scheme employs the combination of the metric with channel diversity factor $metric_{ch\text{-}d}$ and load balancing factor $f_{load}(en_j)$ as multi-pat h selection policy. The weighted average metric is defin ed as:

$$\lambda \cdot metric_{ch\text{-}d} + \gamma \cdot f_{load} \qquad (4)$$

4. Conclusion

In this paper we studied characteristics and challenges on routing protocols of WMNs as well as related research. We proposed a channel diversity based load-balancing cross-layer routing scheme for Wireless Mesh Networks (WMNs). The proposed scheme deals with channel diversity phase and load balancing phase in WMNs. Channel diversity factor $metric_{ch\text{-}d}$ and load balancing factor f_{load} are defined and employed cooperatively as a combined path selection policy.

The simulation work of the proposed scheme is being developed now. Implementation and verification of the algorithm and analysis of the results are our future work.

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