An Efficient Fault Tolerance Path Finding Algorithm for Improving the Robustness of Multichannel Wireless Mesh Networks

Liang-Bi Chen[1,2], *Member*, *IEEE*, Bo-Chuan Cheng[3], You-Chiun Wang[1], *Senior Member, IEEE*,
Katherine Shu-Min Li[1], *Senior Member, IEEE*, and Jing-Jou Tang[4]
[1]Department of Computer Science and Engineering, National Sun Yat-Sen University, Kaohsiung, Taiwan
[2]BXB Electronics Co., Ltd., Kaohsiung, Taiwan
[3]ASE Group, Kaohsiung, Taiwan
[4]Department of Electronic Engineering, Southern Taiwan University of Science and Technology, Tainan, Taiwan
liangbi.chen@gmail.com

***Abstract*—A multichannel wireless mesh network is composed of wireless routers with multiple radio interfaces operating on non-overlapping channels. It provides a network backbone to support multi-hop connectivity between wireless users and the Internet gateways. However, robustness is a critical issue in such networks because wireless links could be prone to error. Simulation results show that the proposed algorithm achieves 100% robustness and fault tolerance when only one link fails. In addition, it can tolerate around 29.71%-45.61% of link failure in the network.**

I. Introduction

Recently, *wireless mesh networks (WMNs)* have attracted significant research attention as they can support broadband and pervasive Internet access. Every WMN router could be equipped with multiple radio interfaces to communicate with neighbors. These routers organize themselves into an ad hoc network to provide the infrastructure between wireless users and Internet gateways. WMNs are self-configured and more flexible against topology changes and link failure. Many WMN applications such as home, community, and enterprise networking have been deployed [1].

When all WMN routers operate on a single channel, the network capacity would be significantly constrained due to serious interference among routers. Therefore, allowing each WMN router to use multiple non-overlapping channels not only alleviates the above capacity constraint but also improves the aggregate network bandwidth [2]. However, this also brings about many challenges such as routing, link scheduling, and channel assignment. This paper aims at improving robustness in such multichannel WMNs.

Consider a multichannel WMN where each router has two radio interfaces operating on different channels. Supposing that some wireless links may encounter failure due to noises or interference, the goal is to find *non-faulty communication paths* between any two routers so that the network robustness is guaranteed. Therefore, a *fault-tolerance pathfinding (FTPF) algorithm* is proposed by modeling the WMN with a modified De Bruijn graph [3]. Then, given the desired path length, FTPF calculates a path containing only non-faulty links between two routers from the graph.

Major contribution of this paper is to develop a path-finding algorithm to allow fault tolerance in a multichannel WMN containing faulty links. Simulation results show that the proposed algorithm could always find a non-faulty communication path between two routers in the case of single-link failure. In addition, even though the network has around 30% faulty links, the proposed algorithm can still perform well, which verifies its effectiveness.

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II. Modified De Bruijn Graph With the Proposed FTPF Algorithm

As can be seen in Fig. 1, when the link or path $e(3,1)$ is faulty, a resilience path $\{e(3, 2), e(2, 4), e(4, 8), e(8, 1)\}$ can be searched for non-faulty WMNs. However, this approach is still constrained by the even nodes, so it may not be appropriate and general enough in modeling real WMN. To solve the above problem with the even-node constraint, a modified De Bruijn digraph model is proposed for fault tolerant smart WMNs in this paper. In this section, the problem definition of *GDB*-based modeling with communication fault tolerance to connect routers in a WMN will be described. Given n and d, a fault tolerant communication graph *GDB* (*FT-GDB*) in $G(d, n)$, G' with link fault tolerance is generated.

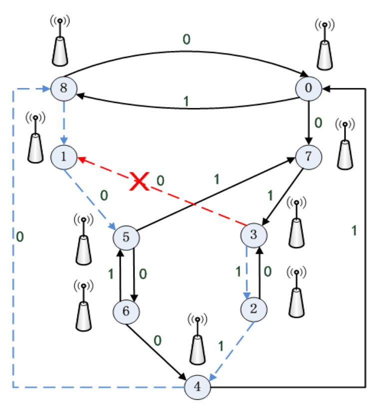

Fig. 1. An improved De Bruijn (*IGDB*) digraph.

Given a further example, as shown in Fig. 2, d=2, a communication path is constructed between the node pair $(0(n_0), 8(n_8))$, thus that can get p=4 and $8_l \equiv 0+1*2^{l-1}+0*2^{l-2}+0*2^{l-3+}0$ and α_i=(0 or 1) $l \leq p$=4.

The proposed fault tolerant path finding (FTPF) algorithm is given in Fig. 3. Given n and d, a fault tolerant communication graph $G(n, d)$, the proposed communication fault tolerant scheme (FTPF algorithm) could be modeled by modifying *GDB*-based algorithm [3] to find resilient paths to reserve fault tolerance in communication.

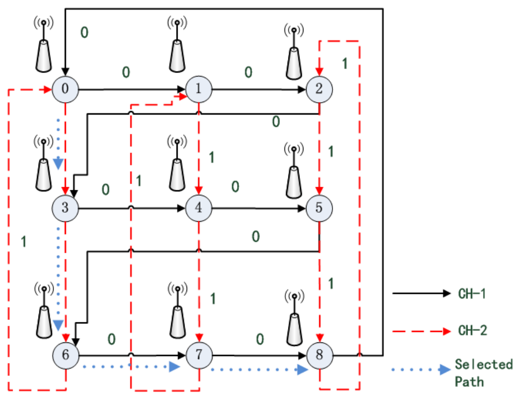

Fig. 2. Link fault tolerant GDB (FT-GDB) in the WMN, with d=2 and l=p=4 from source node 0 to node 8.

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Algorithm 1.   FTPF Algorithm
Input:
n: the number of vertices on the graph G.
u: source node of G.
v : target node of G.
w : the current traversal node of G.
f : target node of G.
d : communication mode (d = 0, CH-1; d = 1, CH-2, …) .
Output:
P: set of Resilience Path on the graph G.
Procedure FTPF{
For i = 0 to n-1 do
   j = ((i+1)+2r) mod n
   If (FindFaultyLink(G,P)=false) Then
      d = 0
      renew P //Record the Resilience Paths
      Exit;
   Else
     d = 1
     renew P
     w=v  //Record the target Node w of Path
   End if
   If u=w Then Exit
   Else
      d = 0
      renew P
      continue
   End if
  End for
End procedure

Procedure FindFaultLink(G, P)
   If (FaultyLink(G,P)!=empty) Then
      Add the FaultyPath of f
         return True
   Else
      return False
   End if
End procedure
```

Fig. 3. FTPF algorithm.

III. Experimental Results

Table I shows that the experimental results for single link and multiple link fault coverage. Eight regions benchmarks are in Column 1. The second column is number of routers, and the third column is number of links by CH-1 and CH-2. The fourth and fifth columns are single link fault coverage by adopting FTPF algorithm method.

The proposed FTPF algorithm provides 100 % fault coverage based on single link fault model. Especially, around average 30% multiple link fault coverage under 1,000 random link fault simulation is listed.

This average 29.71%-45.61% link surviving rate under multiple link faults show that even about 30% edge links are broken simultaneously, the proposed FTPF scheme still maintains the connectivity of the wireless network communication in WMNs.

TABLE I
Experimental Results For Single/Multiple Link Fault Converge

Benchmark	# Router	# Link	Fault Converge (%)			
			FTPF (d=1)	FTPF (d=2)	FTPF (d=3)	FTPF (d=4)
Region 1	8	16	100	31.25	38.18	47.99
Region 2	12	24	100	29.17	37.47	45.56
Region 3	13	26	100	26.92	36.97	45.77
Region 4	14	28	100	32.14	37.5	46.52
Region 5	20	40	100	30.00	35.49	45.15
Region 6	24	48	100	31.25	36.23	44.43
Region 7	27	54	100	27.78	35.54	44.91
Region 8	36	72	100	29.17	34.69	44.59
Avg.	19.24	15.5	100	29.71	36.50	45.61

IV. Conclusion

WMN provides a flexible infrastructure to support broadband and ubiquitous wireless Internet access. While most research efforts target at assigning channels to improve WMN throughput, this paper enhances WMN robustness by searching a non-faulty path between two routers when there exists faulty links in the network. That thus develops a FTPF algorithm to deal with this problem and simulation results show that it can tolerate multiple link failure tolerate averagely 29.71%-45.61% faulty rates under over 1,000 simulation runs.

Reference

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