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RECOVERY OF LINK FAILURES IN IEEE802.11 BASED WMN USING ARS

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***Abstract*—Wireless Mesh Networks (WMNs) are one of the few commonly implemented types of mobile ad-hoc networks (MANETs); several companies offer WMNs for broadband Internet access and for extending the coverage of wireless local area networks. In Wireless Mesh Networks (WMNs),the performance is degraded frequently due to link failures. This paper presents an Autonomous network Reconfiguration System (ARS) that enables a recovery of local link failures autonomously. First, ARS detects link failures by monitoring the network conditions accurately and upon detection of a failure, triggers network reconfiguration.ARS generates a local network reconfiguration plans for each link failure by keeping minimum network changes. This paper proposes to make ARS effective in the presence of less number of Orthogonal channels in IEEE 802.11b based multi radio WMN (mr-WMN) using Ns2 simulator. In comparison with existing schemes, the channel efficiency and the network ability to meet diverse links' QoS demands have been improved by ARS.**

***Keywords* — Multi-radio WMNs, link failures, self-reconfiguration, orthogonal channels, IEEE 802.11,MANET.**

I. INTRODUCTION

A wireless mesh network can be seen as a special type of wireless Ad-hoc network. It is a wireless network made up of radio nodes organized in a mesh topology. Each node forwards messages on behalf of the other nodes. Mesh networks can "self heal", automatically re-routing around a node that has lost power. It often has a more planned configuration, and may be deployed to provide dynamic and cost effective connectivity over a certain geographic area. A mesh network is reliable and offers redundancy. When one node can no longer operate, the rest of the nodes can still communicate with each other, directly or through one or more intermediate nodes. Multi-radio mesh [1] refers to a unique pair of dedicated radios on each end of the link. This means there is a unique frequency used for each wireless hop and thus a dedicated CSMA collision domain.Possible deployment scenarios of WMN are residential zones, highway zones, civilian zones. Fluctuations in wireless link conditions and varying links' QoS requirements cause performance degradation in multi-radio WMN(mr-WMN). For example, some links of a WMN may experience significant channel interference from other co-existing wireless networks. Links in a certain area (e.g., a hospital or police station) might not be able to use some frequency channels because of spectrum etiquette or regulation.

Existing solutions have several limitations to recover from wireless link failures.First, resource allocation algorithms ([14],[15]) often require "global" configuration changes to obtain optimal solution, which are not suitable for the frequent local link failures. Next, in greedy channel-assignment algorithm (e.g., [13]) to achieve the full improvements, in addition to the faulty links configurations of neighbouring mesh routers are also need to be considered. Third, fault-tolerant routing protocols such as local re-routing [5] or multi-path routing [6] can use network –level path diversity for avoiding the faulty links, but consumes more network resources than network reconfiguration.

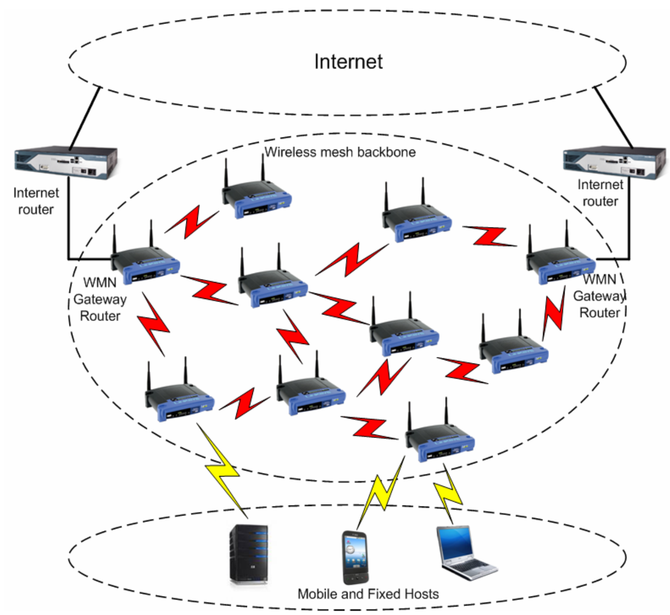

Figure 1: Wireless mesh network architecture.

To overcome the above limitations, we propose an *Autonomous network Reconfiguration System* (ARS) that enables a multi-radio WMN[18] to autonomously reconfigure its local network settings (eg., channel and link association) to recover from local link failures.

A. *Need for self-reconfiguration*

For some kind of cases such as,

- *Link-quality recovery from degradation*
- *To satisfy Dynamic QoS demand*
- *Copying with heterogeneous channel availability*

the necessity of self-reconfiguration is increased.

ARS includes monitoring protocol and reconfiguration planning algorithm. The monitoring protocol in each node accurately monitors the network condition via EAR(highly efficient and accurate link quality measurement technique) [3] and detects network failures in real time by measuring packet delivery ratio and data transmission rate etc,. By accepting current network settings as constraints, ARS generates reconfiguration plans available around a faulty area and identifies the plans require the minimum number of changes. Elects the best plan by applying the various constraints.ARS has been evaluated in large scale network settings via NS2 simulation. ARS performs well than existing failure-recovery methods. ARS planning algorithm finds the reconfiguration plans that optimally satisfy the applications QoS demands and avoids the ripple effects. Improved network throughput and channel efficiency have been achieved by ARS.

II. MODELING OF NETWORK

Multi-radio WMN: A network is assumed to consist of mesh nodes, IEEE 802.11 [2] -based wireless links, and one control gateway.

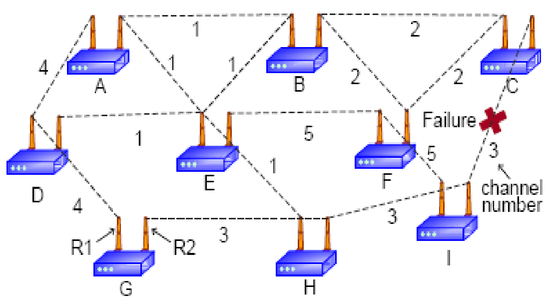

Fig. 2. *Multi-radio WMN*: A WMN has an initial assignment of frequency channels as shown above.

Each mesh node is equipped with n radios, and each radio's channel and link assignments are initially made (e.g., see Fig. 2) by using global channel/link assignment algorithms ([4],[14],[16]). Multiple orthogonal channels are assumed available.

Flow admission: Through management messages , each mesh node send's it's local channel usage and quality information for all outgoing links to the gateway in a periodical manner. Then, based on this information, the admission of requests for voice or video flows are controlled by gateway. For admitted flows, the information about QoS requirements is delivered to the corresponding nodes for resource reservation through the RSVP protocol [7].

RSVP protocol mechanisms provide a general facility for creating and maintaining distributed reservation state across a mesh of multicast or unicast delivery paths. RSVP is simplex, i.e., it makes reservations for unidirectional data flows. RSVP is receiver-oriented, i.e., the receiver of a data flow initiates and maintains the resource reservation used for that flow.

A. *WCETT*:

(1) Take both the loss rate and the data rate of a link into account.
(2) It should be an increasing path metric.
(3) The path metric should explicitly account for the reduction in throughput due to interference among links that operate on the same channel.

Compute the path Metric:

$$\text{WCETT} = (1-\beta) * \sum_{i=1}^{n} ETT_i + \beta * \max_{1 \le j \le k} X_j$$

Where ETTi is expected transmission time of a packet on the link i and *Xj* is the sum of transmission times of hops on channel *j*.
B is a tunable parameter subject to $0 \le \beta \le 1$.

Link failures: Channel-related link failures that we focus on, are due mainly to narrow-band channel failures. Note that hardware failures (e.g., node crashes) or broadband-channel failures (e.g., jamming) are beyond the scope of this paper.

III. ARCHITECTURE OF ARS

A. *Features*

1) *Localized reconfiguration*: ARS generates reconfiguration plans that allow for changes of network configurations only in the vicinity where link failures occurred, while retaining configurations in areas remote from failure locations.

2) *QoS-aware planning*: By estimating the QoS satisfiability of generated reconfiguration plans and deriving their expected benefits in channel utilization, ARS effectively identifies QoS satisfiable reconfiguration plans.

3) *Autonomous reconfiguration via link-quality monitoring*: Based on the measurements and given links' QoS constraints, ARS detects local link failures and autonomously initiates network reconfiguration.

4) *Cross-layer interaction*: ARS actively interacts across the network and link layers for planning. This interaction enables ARS to include a re-routing for reconfiguration planning in addition to link-layer reconfiguration.

B. Modules:

1) Link-Failure Detection
2) Leader Node
3) Network Planner

1) *Link-Failure Detection:* ARS in every mesh node monitors the quality of its outgoing wireless links at every tm (e.g., 10 sec) and reports the results to a gateway via a management message. Second, once it detects a link failure(s), ARS in the detector node(s) triggers the formation of a group among local mesh routers that use a faulty channel, and one of the group members is elected as a leader using bully algorithm[19] and coordinating the reconfiguration.

2) *Leader Node:* **T**he leader node sends a planning-request message to a gateway. If any link is failure group members send request to the particular leader after that the leader node send request to the gateway.

Algorithm 1 ARS Operation at mesh node i

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(1) Monitoring period (t_m)
  for every link i do
    measure link – quality (lq)using EAR monitoring;
  end for
  send monitoring results to a gateway g;
(2) Failure detection and group formation period (t_f)
  if link l violates link requirements r then
    request a group formation on channel c of link l
  end if
  participate in a leader election if a request is received;
(3) Planning period (M , t_p )
  if node i is elected as a leader then
    send a planning request message (c, M ) to a gateway;
  else if node i is a gateway then
    synchronize requests from reconfiguration groups M_n
    generate a reconfiguration plan (p) for M_i;
    send a reconfiguration plan p to a leader of M_i;
  end if
(4) Reconfiguration period (p, t_r )
  if p includes changes of node i then
    apply the changes to links at t;
  end if
  relay p to neighbouring members, if any
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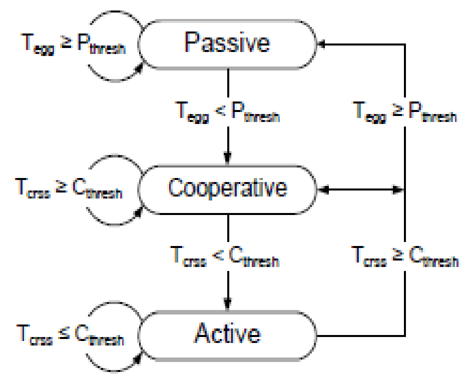
3)Network Planner: It generates reconfiguration plans only in a gateway node. Network planner plans the diversity path for avoiding the faulty links. Then, the gateway synchronizes the planning requests—if there are multiples requests—and generates a reconfiguration plan for the request. Fourth, the gateway sends a reconfiguration plan to the leader node and the group members. Finally, all nodes in the group execute the corresponding configuration changes, if any, and resolve the group.

Overview of EAR

EAR is a Efficient and Accurate link-quality monitoR.EAR is a low-overhead and high-accuracy measurement Framework [3] that is aware of asymmetric wireless links and also easily deployable in 802.11-based WMNs.

Hybrid approach: EAR adaptively selects one of three measurement schemes (passive, cooperative, and active) to opportunistically exploit existing application traffic as probe packets. If there is no application traffic over a link, EAR uses active probing on the link at a reasonable cost. Otherwise, EAR switches itself to passive or cooperative monitoring that gratuitously uses existing traffic for collecting the link-quality information. Figure 2 depicts the EAR's hybrid measurement approach based on the three schemes. When a measuring node(m) has egress traffic, Tegg, to a neighbor node (n), m *passively* monitors the traffic. When Tegg decreases below a certain threshold, Pthresh, m finds another neighbor node to which m has egress traffic and that n can overhear the traffic,



T_{egg} -- Egress traffic
T_{crss} -- Cross traffic
P_{thresh} -- Threshold
C_{thresh} -- Threshold for cooperative monitoring

Fig. 2. Three measurement schemes and their inter-transitions: EAR consists of passive, cooperative, and active measurement phases.

and *cooperatively* (with node n) measures the quality of link m→n. Finally, when the actual traffic over the link is low (< Cthresh), m *actively* measures link quality by unicasting probe packets over the link.

IV. LOCALIZEDNETWORK RECONFIGURATION PLANNING

A *reconfiguration plan* is defined as a set of links' configuration changes (e.g., channel switch, link association) necessary for a network to recover from a link(s) failure on a channel.ARS dividing the reconfiguration planning into three processes—feasibility, QoS-satisfiability, and optimality—and applying different levels of constraints.

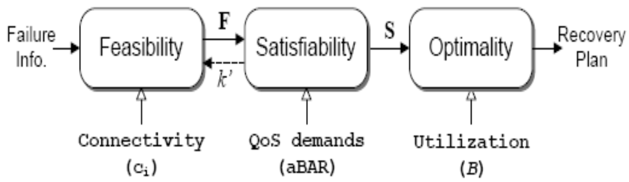


Fig. 3. *Localized reconfiguration planning in ARS*: ARS generates a reconfiguration plan by breaking down the planning process into three processes with different constraints.

A. *Generation of feasible plan*

1) Avoiding a faulty channel: To fix a faulty channel, ARS considers three primitive link changes as shown below.

TABLE I
Definition of link-change in ARS.

Primitive changes	*Description*
Channel switch ($S(A_i,B_j)_{\alpha\to\beta}$)	Radios A_i and B_j of link AB switch their channel (α) to other channel (β).
Radio switch ($R(A_i,B_j)_{\alpha\to\beta}$)	Radios A_i in node A re-associates with radio B_j in node B,tuned in channel (β).
Detouring ($D(A_i,B_j)$)	Both radios A_i and B_j of link AB remove their associations and use a detour path, if exists.

2)Network connectivity maintanence and utilization: ARS takes a two-step approach. ARS first generates feasible changes of each link using the primitives, and then combines a set of feasible changes that enable a network to maintain its own connectivity and maximizes the usage of network resources by making each radio of a mesh node associate itself with at least one link and by avoiding the use of same (*redundant*) channel among radios in one node.

3)Scope of reconfiguration changes control: ARS uses a k-hop reconfiguration parameter.Starting from a faulty link(s), ARS considers link changes within the first k hops and generates feasible plans. If ARS cannot find a local solution, it increases the number of hops (k) so that ARS may explore a broad range of link changes.

B. *Evaluating QoS Satisfiability*

Among a set of feasible plans F, ARS now needs to identify QoS-satisfying reconfiguration plans by checking if the QoS constraints are met under each plan. ARS has to solve the following challenges to find the QoS satisfiable plans.

1)Estimation of Per-link Bandwidth: ARS estimates an individual link's capacity (C), based on measured (or cached) link-quality information—packet-delivery ratio and data-transmission rate.

*2)Per-link bandwidth satisfiability examination:*ARS uses the expected busy air-time ratio(BAR) of each link to check the link's QoS satisfiability.

$$BAR=q/c$$

q=link's bandwidth requirement
c=Individual link's capacity

To satisfy bandwidth requirement,BAR must not exceed 1.0 for a link. If multiple links share the air-time of one channel, ARS calculates aggregate BAR (*aBAR*) of end-radios of a link, which is defined as $aBAR(k) = \sum_{l \in L(k)} q_l/c_l$, where k is a radio ID, l a link associated with radio k, L(k) the set of directed links within and across radio k's transmission range.

3)Avoiding cascaded link failures:To avoid the occurrence of cascaded link failure,ARS also estimates the QoS-satisfiability of links one hop away from member nodes whose links' capacity can be affected by the plan.

C. *Optimal Plan Selection*

ARS chooses the optimal plan after satisfy the above constraints by the criteria of evenly dist ributed link capacity.

V. PERFORMANCE EVALUATION

Via ns2[11] simulation,I have formed grid topology with 25 nodes and each node is equipped with multiple radios based on their proximity to a gateway.The gateway is equipped with three radios and others are assigned with two radios.Shadowing propagation model[17] is used and IEEE 802.11b standard for channel assignment has been used.

TABLE II
Comparison of various standards in IEEE 802.11

802.11 protocol	Freq. (GHZ)	Bandwidth (MHZ)	Data rate per stream(Mbit	Modulation

			/s)	
A	5	20	6,9,12,18,24 ,36,48,54	OFDM
B	2.4	20	5.5,11	DSSS
G	2.4	20	6,9,12,18,24 ,36,48,54	OFDM, DSSS

IEEE 802.11a has 13 orthogonal channels at 5 GHZ spectrum and IEEE 802.11b has 3 orthogonal channels at 2.4 GHZ.Previously DSDV had been used for routing.In This paper link state routing protocol (OLSR) [12] is proposed and WCETT [8] routing metric is used.

OLSR is based upon the traditional link state algorithm. Each node maintains topology information about the network by periodically exchanging link state messages. The optimization introduced by OLSR is that it minimizes the size of each control message and the number of nodes re-broadcasting a message by employing the multipoint relay strategy.The local one hop and two hop neighborhood is discovered through periodic exchange of HELLO messages. Thereafter each node selects some one hop neighbors to be its multi point relay(MPR) in a way that all two hop neighbors can be reached through at least one of the selected members of the MPR set. Nodes that are not MPRs can receive and process each control packet but do not retransmit them and do not announce network topology to other nodes in the network. Nodes that are MPRs of at least one node forward packets for the nodes that selected them as MPRs and announce all nodes that selected them as MPR by topology content packets to the entire network. Based on its one hop and two hop neighborhood and the topology information each node calculates an optimal route (with regard to hop count) to every known destination in the networks and stores it in its routing table.

ARS is implemented as an agent in a routing protocol.Multiple UDP flows between a gateway and mesh nodes are generated.Effectiveness of ARS is measured in meeting various QoS requirements in a mr-WMN.The improvement of available capacity that ARS can generate is evaluated.

In Fig.4,Throughput has been calculated while in case of ARS implementation. **Throughput** or **network throughput** is the average rate of successful message delivery over a communication channel.The throughput is usually measured in bits per second (bit/s or bps), and sometimes in data packets per second or data packets per time slot.Here the throughput before link failure and after the reconfiguration are almost equal.

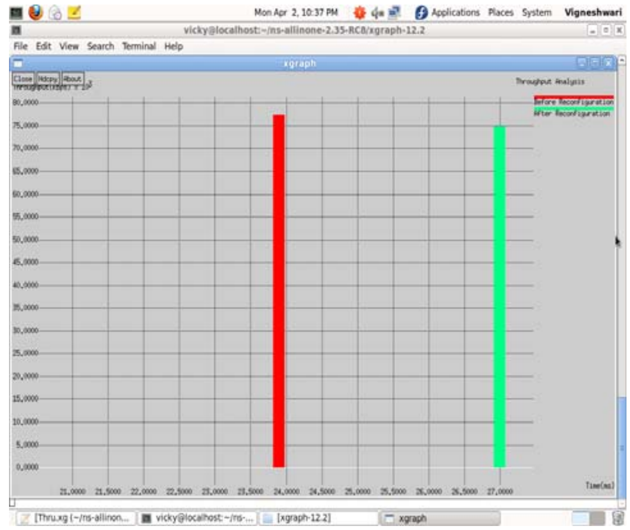


Fig 4. Throughput of ARS

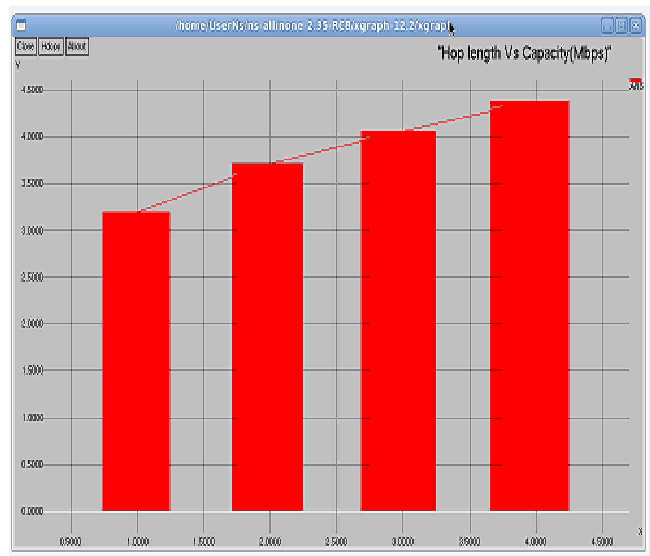


Fig.5 Improvement in link's capacity

In Fig.5,it has been analyzed that the link's capacity is improved by the reconfiguration plans while increasing the hop length or count from a faulty link(s).

Fig6. Datarate Vs ARS Attempted

In Figure.6,ARS has been evaluated on IEEE 802.11b standard.While increasing Datarate,some of the links cannot be able to satisfy the QoS demands and link failure might be occured.So ARS has attempted to recover from link failures and satifying the new bandwidth demands automatically.

Fig.7 Data Rate vs Packet Delivery Ratio

In Fig.7,to generate more bandwidth demands from applications,data rate was increased gradually and the corresponnding packet delivery ratio has been calculated for each.It can be realized that the PDR increases even in the case of increasing data rate.

VI. CONCLUSION

In this paper, an Autonomous network Reconfiguration System (ARS) is evaluated in IEEE 802.11b based multi-radio wireless mesh network having 3 orthogonal channels to autonomously recover from wireless link failures.By channel diversity and link re-associaion,reconfiguration plans are identified effectively to satisfy application's QoS constraints and requires only local network configuration changes.Thus the existing network connectivity are kept as much as possible.ARS is worked properly eventhough in the presence of less number of orthogonal channels ie., on IEEE 802.11b based WMN.And flow assignment and routing are also jointly considered to achieve the better performance by reconfiguration.

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