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QARS for Self Reconfiguration Mechanism in Wireless Mesh Networks

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***Abstract*—Wireless mesh networks (WMNs) are being developed actively and deployed widely for a variety of applications. Wireless Mesh Network (WMN) is a communication network made up of radio nodes organized in a mesh topology. Mesh Network has the advantages of fast implementation, easy maintenance and low direct investment while comparing with the existing networks. Multi-hop wireless mesh networks (WMNs) experience frequent link failures due to channel interference, dynamic obstacles, and bandwidth demands. These failures cause severe performance degradation in WMN. This paper proposes a Quick Autonomous Reconfiguration System (QARS) that enables a multi-radio WMN to autonomously recover from local link failures. QARS first searches for feasible local configuration changes available around a faulty area, and identifies reconfiguration plans that require the minimum number of changes for the healthy network settings. QARS using enhanced bully algorithm for leader node selection helps in times of link failures in the network.**

***Index Terms*— Multi-Radio Wireless Mesh Networks (mr-WMNs), Leader Node Selection, Self-Reconfigurable Networks, Wireless Link Failures**

I. Introduction

Wireless mesh networks (WMNs) have emerged as a key technology for next-generation wireless networking for numerous applications e.g., broadband home networking, community and neighborhood networks, enterprise networking, building automation, etc. Also it is being developed actively and deployed for a variety of applications, such as public safety, environment monitoring a wireless Internet services. Wireless mesh networks often consist of mesh clients, mesh routers and gateways. The mesh clients are often laptops, cell phones and other wireless devices while the mesh routers forward traffic to and from the gateways which may but need not connect to the Internet. 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. The mesh routers may be mobile, and be moved according to specific demands arising in the network.

There are many solutions for WMNs to recover from failure, but they have several limitations such as they often require "global" configurations, provides solution by changing settings of only the faulty link(s),but might not be able to realize full improvements, which can only be achieved by considering configurations of neighboring mesh routers in addition to the faulty link(s).Fault-tolerant routing protocols, such as local re-routing or multi-path routing , can use network-level path diversity for avoiding the faulty links. However, they rely on detour paths or redundant transmissions, which may require more network resources than link level network reconfiguration.

The Quick Autonomous Network Reconfiguration System that allows a multi-radio WMN to autonomously reconfigure its local network settings. QARS identifies reconfiguration plans that require the minimum number of changes for the healthy network settings with the help of the enhanced bully algorithm [12]. QARS also includes a monitoring protocol that enables a WMN to perform real-time failure recovery in conjunction with the planning algorithm.

II. Related Works

ARS algorithm [2] focus on Autonomous network Reconfiguration System that enables a multi-radio WMN to autonomously recover from local link failures to preserve network performance. ARS generates necessary changes in local radio and channel assignments in order to recover from failures.

The greedy channel-assignment algorithm, which considers only local areas in channel assignments, might do better in reducing the scope of network changes than the channel assignment algorithms. However, this approach still suffers from the ripple effect, in which one local change triggers the change of additional network settings at neighboring nodes due to association dependency among neighboring radios.

Joint channel assignment routing [3] and scheduling problem that can model the interference and fairness constraints and it is also able to account for the number of radios at each of the wireless nodes. A novel flow transformation technique to design an efficient channel assignment algorithm that can assign channels to node radios while ensuring that maximum data can be transmitted on specified traffic routes.

ETX algorithm [4] focus on ETX finds paths with the fewest expected number of transmissions required to deliver a packet all the way to its destination. The metric predicts the number of retransmissions required using per-link measurements of packet loss ratios in both directions of each wireless link. The primary goal of the ETX design is to find paths with high throughput, despite losses.

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Interference channel assignment [5] focus on model Dynamic channel assignment interference between the routers. Interference-aware channel assignment algorithm and a corresponding channel assignment protocol aimed at improving the capacity of wireless mesh networks by making use of all available non-overlapping channels.

For the selection of the leader node among the nodes there are several leader node selection algorithms available. Most of them have several drawbacks.

The bully algorithm [10] that is used for the leader node selection has some drawbacks. (a) Every time a node recovers from a crash failure, it initiates an election, which consumes significant system resources. (b) Although this algorithm ensures liveness, it sometimes fails to meet the safety condition. This can happen when a former leader node is replaced by a node with the same id number while the election procedure is in progress. The newly elected node and the former leader node will both announce themselves as leaders simultaneously. (c) This algorithm elects a new leader node with the help of a number of redundant elections.

For modified bully algorithm [11] also there are several drawbacks .This algorithm does not guarantee to stop more than one simultaneous election. This usually happens when a lower numbered node detects the failure of the leader while an election is in progress which was initiated by another node of higher id. Because of its ignorance about the ongoing election it will start another election, which causes more message generation in the system. Moreover, the failure detector modules of more than one node may detect the crash of the current leader node at exactly the same time and may initiate more than one election in parallel.

III. PROPOSED WORK

The proposed work has the following Strategies

- *Localized Reconfiguration*: Based on multiple channels and radio associations available, QARS generates reconfiguration plans that allow for changes of network configurations only where link failures occurred while retaining configurations in areas remote from failure locations.
- *QoS-aware Planning:* QARS effectively identifies QoS-satisfiable reconfiguration plans by estimating the QoS satisfiability of generated reconfiguration plans and deriving their expected benefits in channel utilization.

A. QARS Architecture

QARS architecture contains the following components.
Network planner: Generates reconfiguration plans only in a gateway node.
Group organizer: Forms a local group among mesh routers.
Failure detector: Periodically interacts with a network monitor and maintains an up-to-date link state table.
Routing table manager: QARS obtains or updates states of a system routing table [9].
Network monitor: Efficiently monitors link-quality and is extensible to support as many multiple radios.
NIC manager: Effectively reconfigures NIC's settings based on a reconfiguration plan from the group organizer.

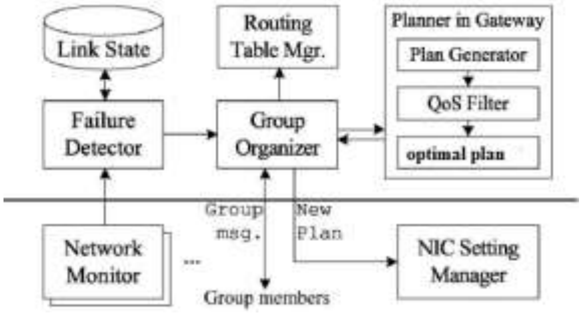

Fig 1 QARS Architecture

B. QARS Algorithm

Algorithm: QARS Operation at mesh node
(1) Monitoring period
1: for every link do
2: measure link-quality using passive monitoring;
3: end for
4: send monitoring results to a gateway;
(2) Failure detection and group formation period
5: if link violates link requirements then
6: request a group formation on channel of link;
7: end if
8: participate in a leader election if a request is received;
(3) Planning period
9: if node is elected as a leader then
10: send a planning request message to a gateway;
11: else if node is a gateway then
12: synchronize requests from reconfiguration groups
13: generate a reconfiguration plan
14: send a reconfiguration plan to a leader
15: end if
(4) Reconfiguration period
16: if includes changes of node then
17: apply the changes to links
18: end if
19: relay the plan to neighboring members, if any

C. QARS Operation

QARS Operation at mesh node:

1) *Monitoring period*, for every link measure link-quality using passive monitoring and sends monitoring results to a gateway.

2) *Failure detection and group formation period*, if link violates link requirements then request a group formation on channel of link participate in a leader election using the enhanced bully algorithm if a request is received.

3) *Planning period*, if node is elected as a leader then send a planning request message to a gateway else if node is a gateway then synchronize requests from reconfiguration groups generate a reconfiguration plan send a reconfiguration plan to a leader.

4) *Reconfiguration period*, if includes changes of node then find the transmission at the reduced delay apply the changes to links.

Feasible Plan Generation:

Generating feasible plans is essentially to search all legitimate changes in links' configurations and their combinations around the faulty area. QARS identifies feasible changes that help avoid a local link failure but maintain existing network connectivity as much as possible.

i) Avoiding a Faulty Channel

QARS first has to ensure that the faulty link needs to be fixed via reconfiguration. Specifically, to fix a faulty link(s), QARS can use: 1) a channel-switch where both end-radios of link AB can simultaneously change their tuned channel; 2) a radio-switch where one radio in node A can switch its channel and associate with another radio in node B.

Table I
Definition of Link-Change in QARS. Each Change Represents A Primitive Link Change In Channel, Association, Or Route.
Multiple Changes Can Be Jointly Used To Represent Changes of Multiple Links

Primitive changes	Description
Channel switch $(S(A_i, B_j)_{\alpha\rightarrow\beta})$	Radios A_i and B_j of link AB switch their channel (α) to other channel (β).
Radio switch $(R(A_i, B_j)_{\alpha\rightarrow\beta})$	Radio 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.

ii) Maintaining Network Connectivity and Utilization

QARS needs to maintain connectivity with the full utilization of radio resources. Because each radio can associate itself with multiple neighboring nodes, a change in one link triggers other neighboring links to change their settings. To coordinate such propagation, QARS takes a two-step approach. QARS 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.

D. *Enhanced Bully Algorithm*

In distributed computing systems, if an elected leader node fails the other nodes of the system need to elect another leader. The bully algorithm [10] is a classical approach for electing a leader in a synchronous distributed computing system. But it has several drawbacks. So here using the enhanced bully algorithm [12] for leader node election. This enhancement of the bully algorithm, requiring less time complexity and minimum message passing.

In a leader election algorithm the following assumptions are made: (a) each node must have a unique id determined by the operating system; (b) each node knows the id of the others; (c) nodes are not aware of the current state of other nodes. Along with these, the following requirements must be met by the algorithm:

1) Safety. All the live nodes must agree on the elected leader.

2*) Liveness*. After participating in an election all the live nodes and the elected leader node must come into a position where all of them are in operational state normal.

All the nodes of a synchronous distributed system are divided into two sets: Candidate and Ordinary. Candidate is comprised of [N=2] nodes, where N is the number of nodes in the system. The other nodes will be in Ordinary, such that any node in Candidate has a higher node id than any node in Ordinary. Every node of the system should be aware of the other nodes‟ sets and ids.

The Election Procedure of enhanced bully are Ideal Case(IC) -failure of ordinary or candidate node, Candidates Failure Case (CFC), Electioneer Failure Case (EFC), Simultaneous Election Case (SEC), and Node Revival Case (NRC).Here only focusing on the Simultaneous Election Case.

- *Simultaneous Election Case (SEC):* More than one node may detect that the leader node has crashed. In that case, detector nodes will initiate separate elections simultaneously. A potential node in Candidate Set to become leader may receive more than one election message simultaneously. A detector node must send election message to the potential nodes and start its clock for Tel,i time-out period. Potential nodes that received election message will reply with ok message only to the highest id node of all the sender nodes. Here after sending ok messages, nodes will wait for Tok,i time. Upon receiving ok messages the detector node declares the new leader by broadcasting coordinator message to all nodes of the system.

Suppose node 10 is the leader and it crashes, and nodes 2, 5 and 7 detect that simultaneously. Now nodes 2, 5 and 7 will initiate three separate elections by sending election messages to Candidate, as shown in Figure 2.

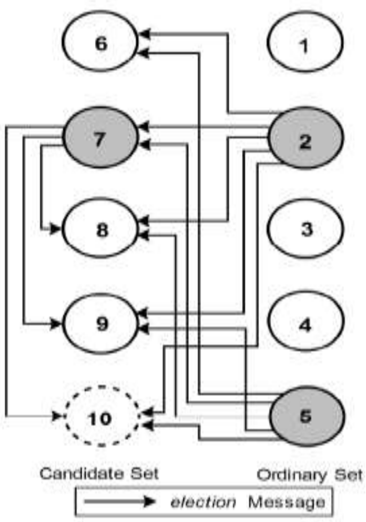

Fig 2 Election initialization in parallel.

Upon receipt of election messages nodes 9 and 8 will send ok message to node 7. At the same time nodes 7 and 6 will send ok message to node 5 as shown in Figure 3, because to each of these nodes in Candidate it is the highest id node among the detector nodes. After sending ok messages, nodes will start their own timer to wait $T_{ok,i}$ time to receive coordinator message. Detector nodes 7, 5 and 2 wait up to $T_{el,7}$, $T_{el,5}$, $T_{el,2}$ times respectively to receive ok message. However, node 7 knows about the highest live node id, and declares the new leader, i.e., node 9, and Figure 4 shows that.

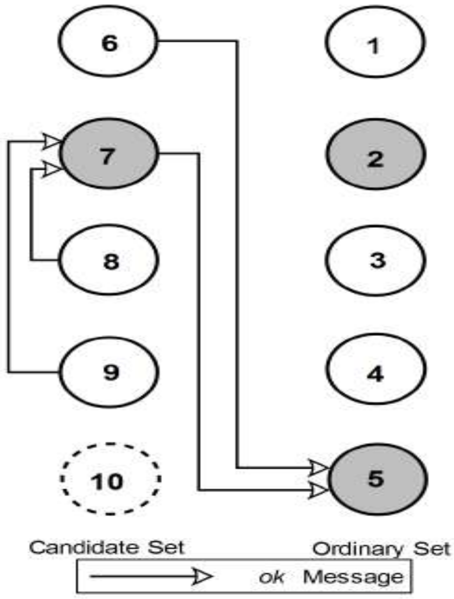

Fig 3. *ok* message to the highest id electioneer nodes

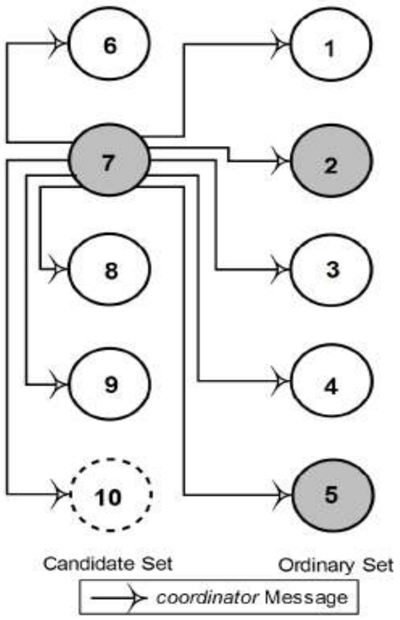

Fig 4. Declaration of the new leader node

IV. PERFORMANCE ANALYSIS

A. Simulation Model

Ns-2 is used in our simulation study. Throughout the simulation, we are use 25 nodes in an area of routing protocol of network failures. First, to generate users traffic, multiple flows between nodes is randomly-chosen. Second, to create network failures, channel faults are injected at a random time point. Random bit-error is used to emulate channel-related link failures and lasts for a given failure period.

B. Evaluation Results

The performance evaluation can be done in this module. The throughput, channel efficiency, delay and quality of service can be evaluated in the performance evaluation. Graphical representations can be also made for the evaluation.

QARS enhances chance to meet the varying QoS demands. We use static, WCETT routing metric [7] that finds a path with diverse channels and QARS for reconfiguration. We expect the effectiveness of QARS in meeting the varying QoS requirements in a multi radio-WMN.

When we increase the hop count from a faulty link, we are able to measure the capacity improvement achieved by the reconfiguration plans. In addition, we are trying to calculate the capacity gain per change as the cost-effectiveness of reconfiguration planning with different values. QARS can improve the available links capacity by increasing the reconfiguration range.

IV. CONCLUSION

In wireless mesh networks the new mechanism, the Quick Autonomous Network Reconfiguration System enables a multi radio wireless mesh networks to autonomously recover from wireless link failures. QARS generates an effective reconfiguration plan that requires only local network configuration changes by exploiting channel, radio, and path diversity. QARS also includes a monitoring protocol that enables a WMN to perform real-time failure recovery in conjunction with the planning algorithm. QARS first searches for feasible local configuration changes available around a faulty area, based on current channel and radio associations. Then, by imposing current network settings as constraints, QARS identifies reconfiguration plans that require the minimum number of changes for the healthy network settings. It can improve the channel-efficiency and the ability of meeting the applications bandwidth demands. QARS uses the enhanced bully algorithm for leader node selection. QARS can thus improve the performance.

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