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Autonomous Reconfiguration for Wireless Mesh Networks

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Abstract: Wireless Mesh Networks (WMNs) experience of frequent link failures. These failures cause severe performance degradation in WMNs. This work presents an Autonomous network Reconfiguration system (ARS) that enables a multi-radio WMN to autonomously make progress from local link failures to safeguard network performance.

Key words: Wireless Mesh Network (WMN) · Blacklist-Aided Forwarding (BAF) · Automatic network reconfigurable system (ARS)

INTRODUCTION

A wireless mesh network (WMN) is a connections network made up of radio nodes organized in a mesh topology. Fig.1.1 shows a typical wireless mesh network. Wireless mesh networks often consist of mesh clients, mesh routers and gateways. Around a number of application domains such as the mobile networks, ad hoc networks, ubiquitously and pervasive computing, sensor networks and so on. To provide better service Wireless mesh networks (WMNs) is used. WMN are dynamically self-organized and self- configured, with the nodes in the network. A wireless mesh network (WMN) is a mesh network created through the connection of wireless access points installed at each network user's point. Each network user is also a provider, forwarding data to the next node. A mesh network is reliable and offers redundancy. A wireless mesh network often has a more planned configuration and may be deployed to provide dynamic and cost effective connectivity over a certain geographic area. An adhoc network, on the other hand, is formed adhoc when wireless devices come within communication range of each other. The mesh routers may be mobile and be moved according to specific demands arising in the network. Often the mesh routers are not limited in terms of resources compared to other nodes in the network and thus can be exploited to perform more resource intensive functions.

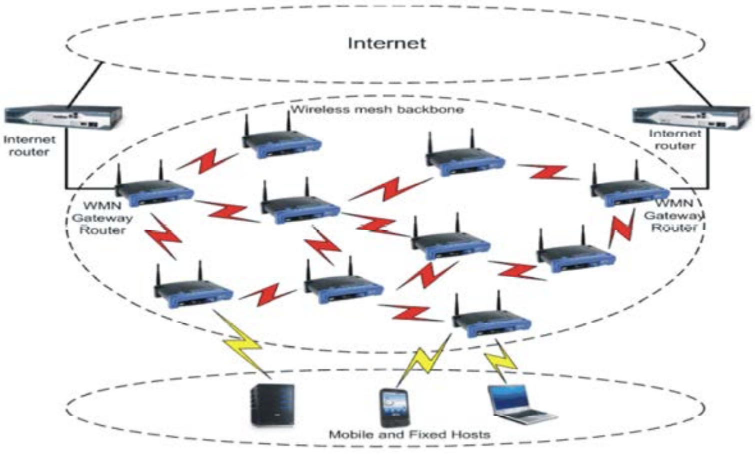

Fig. 1: Wireless Mesh Networks

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Literature Review: Multihop infrastructure wireless mesh networks propose increased reliability, coverage and decreases the equipment costs over their single-hop counterpart, WLAN. Equipping wireless routers with multiple radios further improve the capacity by transmit over multiple radios simultaneously using orthogonal channels. Efficient channel assignment and routing is essential for throughput optimization of mesh clients. Efficient channel assignment schemes can greatly reduce the interference effect of close-by transmissions; effective routing schemes can alleviate potential congestion on any gateways to the internet, thereby improving per-client throughput. Unlike previous heuristic approaches, in this paper, we learn that it mathematically formulates the joint channel assignment and routing problem, taking into account the interference constraints, the number of channels in the network and the number of radios available at each mesh router. This formulation is then used to develop a solution for our problem that optimizes the overall network throughput subject to fairness constraints on allocation of limited wireless capacity among mobile clients. The performance of these algorithms is within a stable factor of that of any optimal algorithm for the joint channel assignment and routing problem. The evaluation demonstrates that the algorithm can effectively exploit the increased number of channels and radios and it perform much better than the theoretical worst case bounds [1, 2].

Even though multiple non-overlapped channels exist in the 2.4 GHz and 5 GHz spectrum, most IEEE 802.11-based multi-hop adhoc networks today use only a single channel. As a result, these networks not often can fully exploit the aggregate bandwidth available in the radio spectrum provisioned by the standards [3]. This prevents them from being used as an ISP's wireless last-mile access network or as a wireless enterprise backbone network. This paper proposes a multi-channel wireless mesh network (WMN) architecture (called Hyacinth) that equips each mesh network node with multiple 802.11 network interface cards (NICs). The focus design issues of this multi-channel WMN architecture are channel assignment and routing [4]. It shows that intelligent channel assignment is serious to Hyacinth's performance, present distributed algorithms that utilize only local traffic load information to dynamically assign channels and to route packets and compare their performance against a centralized algorithm that performs the same functions. Through an extensive simulation study, it is seen that even with just 2 NICs on each node, it is possible to improve the network throughput by a factor of 6 to 7 when compared with the conventional single-channel adhoc network architecture. The paper [5] also describes and evaluates a 9-node Hyacinth prototype that is built using commodity PCs each equipped with two 802.11a NICs.

Static broadband wireless networks, due to their ease of deployment, are likely to proliferate in the near future. The major stumbling block, however, is that wireless links are prone to external interference, channel fading, inclement weather, etc. Therefore scalable and reliable routing despite frequent link quality fluctuations is needed for accelerating the growth of these networks. Most of the wireless routing schemes proposed in the literature are less suitable for these networks, as they are designed primarily for mobile adhoc networks with dynamic and unpredictable topologies. A novel link-state-based blacklist-aided forwarding (BAF) approach is proposed that takes advantage of the fact that the nodes and therefore their adjacencies are relatively static, for scalable packet delivery in static wireless networks. Under BAF, each packet carries a blacklist, a minimal set of degraded-quality links encountered along its path and the next hop is determined based on both its destination and blacklist [5]. BAF provides loop-free delivery of packets to reachable destinations regardless of the number of degraded links in the network. The performance of BAF is evaluated and it is shown that it is not only reliable but also scalable [6].

In an adhoc network, all communication is done over wireless media, typically by radio through the air, without the help of wired base stations. Since direct communication is allowed only between adjacent nodes, distant nodes communicate over multiple hops. The quality-of-service (QoS) routing in an adhoc network is difficult because the network topology may change constantly and the available state information for routing is inherently imprecise. Here distributed QoS routing scheme is proposed that selects a network path with sufficient resources to satisfy a certain delay (or bandwidth) requirement in a dynamic multihop mobile environment. The proposed algorithms work with imprecise state information. Multiple paths are search in parallel to find the most qualified one. Fault-tolerance techniques are brought in for the protection of the routing paths when the nodes move, join, or leave the network. These algorithms consider not only the QoS requirement, but also the cost optimality of the routing path to improve the overall network performance. Wide spread simulations show that high call admission ratio and low-cost paths are achieved with modest routing overhead. The algorithms can tolerate a high degree of information imprecision [7].

Proposed System: ARS is a distributed system that is easily deployable in IEEE 802.11-based MR-WMNs. Running in every mesh node; ARS supports self-reconfigurability via the following distinct features:

- Localized reconfiguration: Based on multiple channels and radio associations available, 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.
- QoS-aware planning: ARS effectively identifies QoS- satisfiable reconfiguration plans by: estimating the QoS satisfiability of generated reconfiguration plans deriving their expected benefits in channel utilization.
- Autonomous reconfiguration via link-quality monitoring: ARS accurately monitors the quality of links of each node in a distributed manner. Furthermore, based on the measurements and given links' QoS constraints, ARS detects local link failures and autonomously initiates network reconfiguration.
- Cross-layer interaction: ARS actively interacts across the network and link layers for planning. This interaction enables ARS to include a rerouting for reconfiguration planning in addition to link-layer reconfiguration. ARS can also maintain connectivity during recovery period with the help of a routing protocol.

Planning for Localized Network Reconfiguration: The core function of ARS is to systematically generate localized reconfiguration plans. 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 and there are usually multiple reconfiguration plans for each link failure. Existing channel-assignment and scheduling algorithms seek "optimal" solutions by considering tight QoS constraints on all links, thus requiring a large configuration space to be searched and hence making the planning often an NP-complete problem. In addition, change in a link's requirement may lead to completely different network configurations. By contrast, ARS systematically generates reconfiguration plans that localize network changes by dividing the reconfiguration planning into three processes - feasibility, QoS satisfiability and optimality - and applying different levels of constraints.

Fig. 2: Localized reconfiguration planning in ARS.

As depicted in the Fig. 2 [8], ARS first applies connectivity constraints to generate a set of feasible reconfiguration plans that enumerate feasible channel, link and route changes around the faulty areas, given connectivity and link-failure constraints. Then, within the set, ARS applies strict constraints (i.e., QoS and network utilization) to identify a reconfiguration plan that satisfies the QoS demands and that improves network utilization most.

Feasible Plan Generation: Generating feasible plans is essentially to search all legitimate changes in links' configurations and their combinations around the faulty area. Given multiple radios, channels and routes, ARS identifies feasible changes that help avoid a local link failure but maintain existing network connectivity as much as possible. However, in generating such plans, ARS has to address the following challenges [9]:

Avoiding a Faulty Channel: ARS first has to ensure that the faulty link needs to be fixed via reconfiguration.

Maintaining Network Connectivity and Utilization: While avoiding the use of the faulty channel, ARS 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, 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. Furthermore, for the combination, ARS 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.

Controlling the Scope of Reconfiguration Changes: ARS has to limit network changes as local as possible, but at the same time it needs to find a locally optimal solution by considering more network changes or scope. To make this tradeoff, ARS uses a -hop reconfiguration parameter.

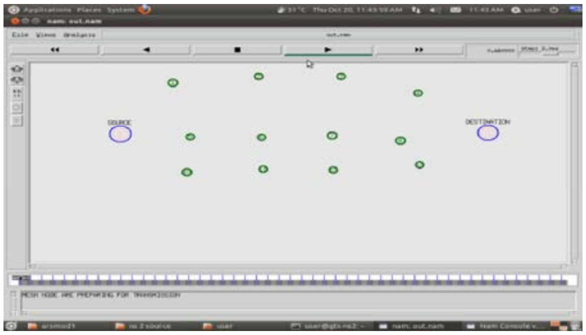
Starting from a faulty link(s), ARS considers link changes within the first hops and generates feasible plans. If ARS cannot find a local solution, it increases the number of hops so that ARS may explore a broad range of link changes.

Simulation Result:

Below figures shows the mesh nodes preparing for transmission and data are transmitted in the network.

In Greedy Algorithm, Local rerouting and ARS shows the transmission of data in different route and if the failure occurred alternate path is defined and data are transmitted.

Network Formation



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MESH NODE ARE PREPARING FOR TRANSMISSION
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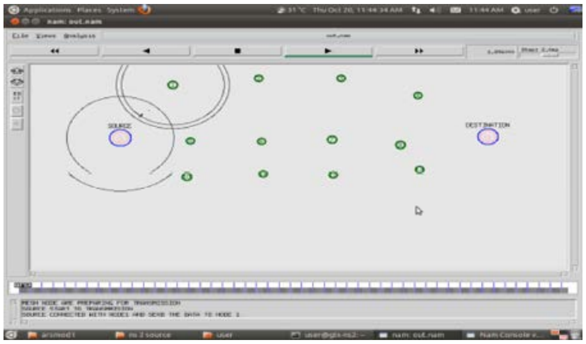
Fig. 3: Mesh Nodes Preparing for Transmission



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MESH NODE ARE PREPARING FOR TRANSMISSION
SOURCE START TO TRANSMISSION
SOURCE CONNECTED WITH NODES AND SEND THE DATA TO NODE 1
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Fig. 4: Transmission of data in the network

Greedy Algorithm:

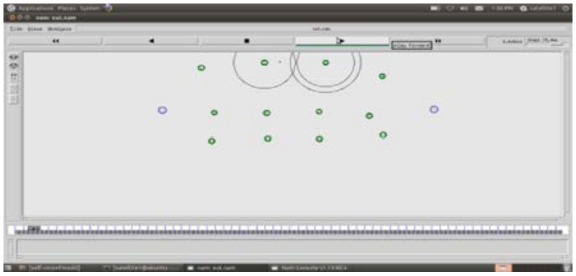

Fig. 5: Transmission of packets via Route 1

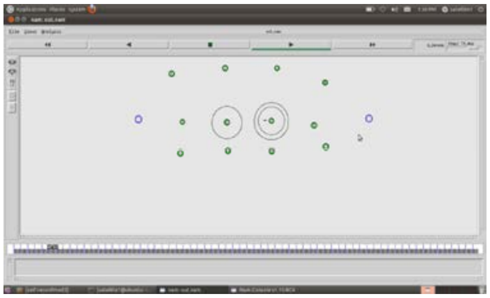

Fig. 6: Transmission of packets via Route 2

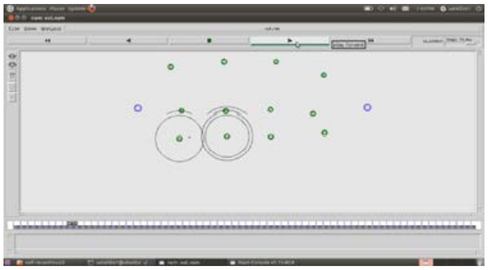

Fig. 7: Transmission of packets via Route 3

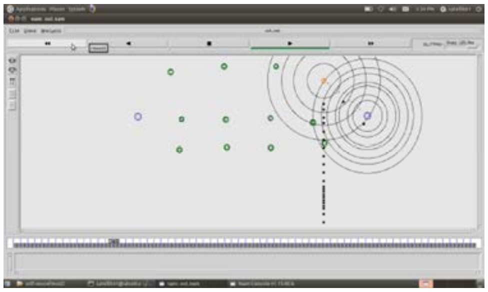

Fig. 8: Link Failure in Route 1

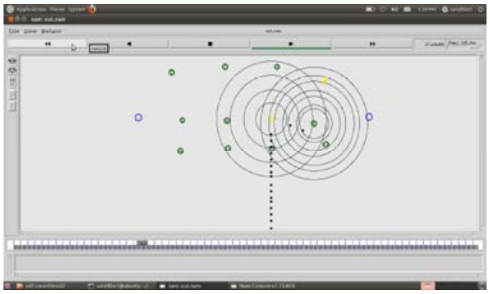

Fig. 9: Alternate path taken yet failure occurs

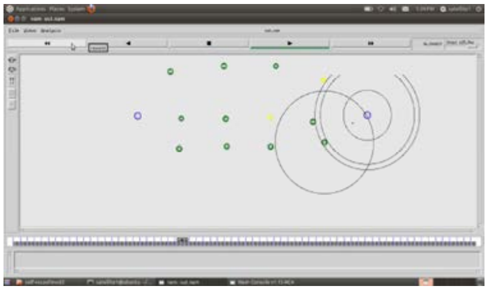

Fig. 10: Successful transmission of packets

Local Rerouting:

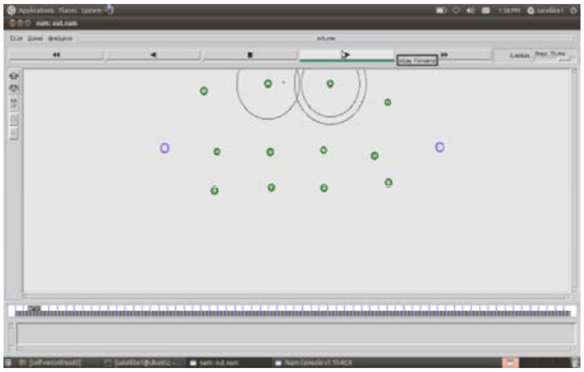

Fig. 11: Transmission of packets via Route 1

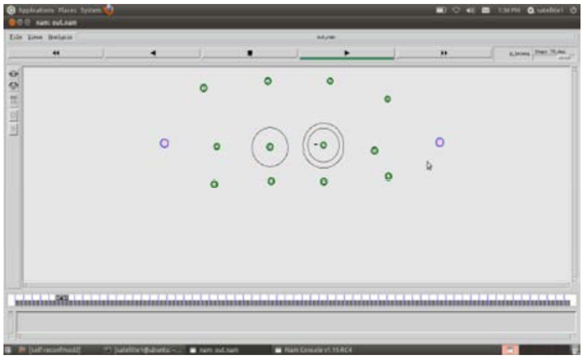

Fig. 12: Transmission of packets via Route 2

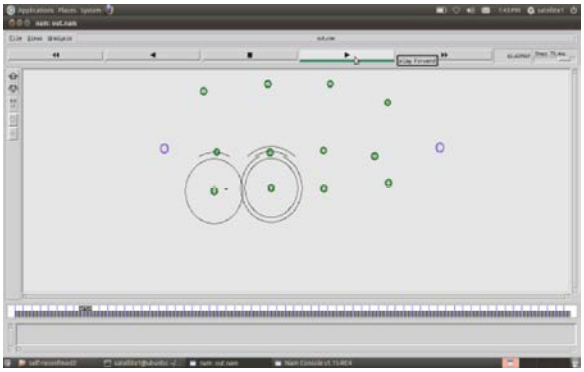

Fig. 13: Transmission of packets via Route 3

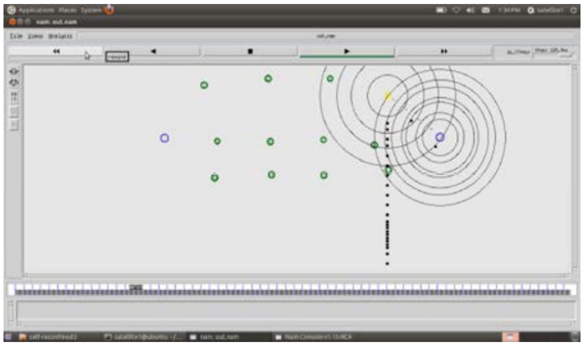

Fig. 14: Link Failure in Route 1

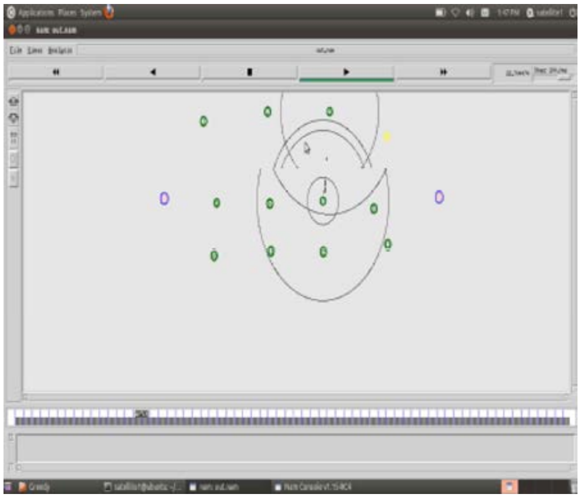

Fig. 15: Rerouting the packets to avoid faulty link

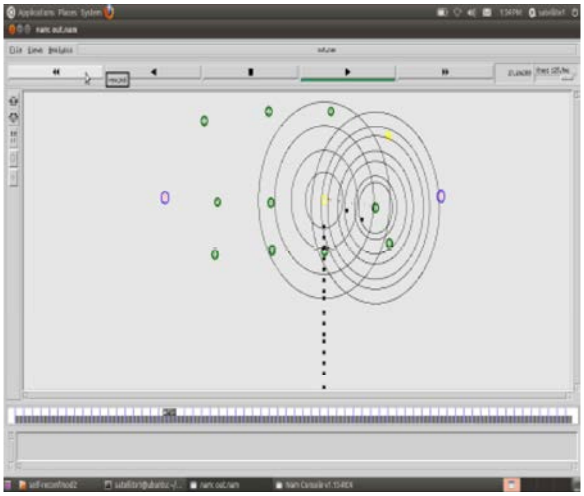

Fig. 16: Link failure in alternate path

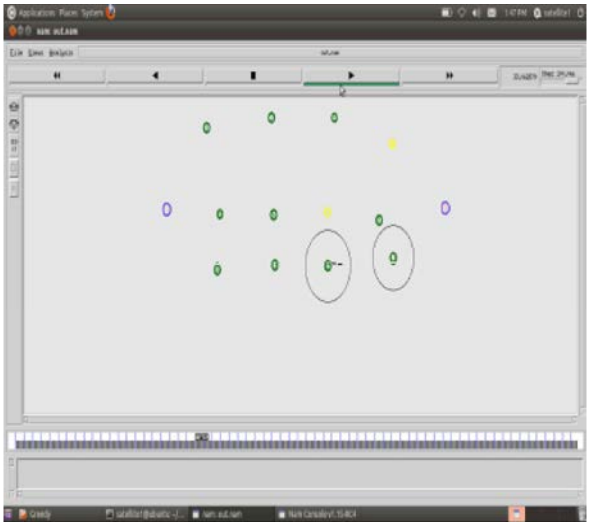

Fig. 17: Rerouting again for successful transmission

Autonomous Network Reconfiguration System

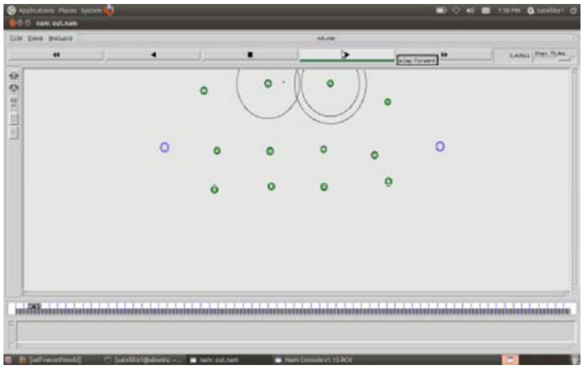

Fig. 18: Transmission of packets via Route 1

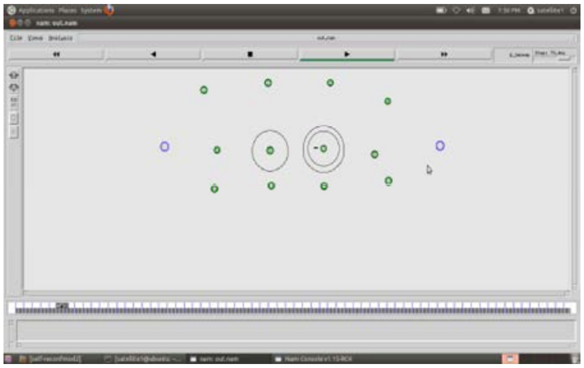

Fig. 19: Transmission of packets via Route 2

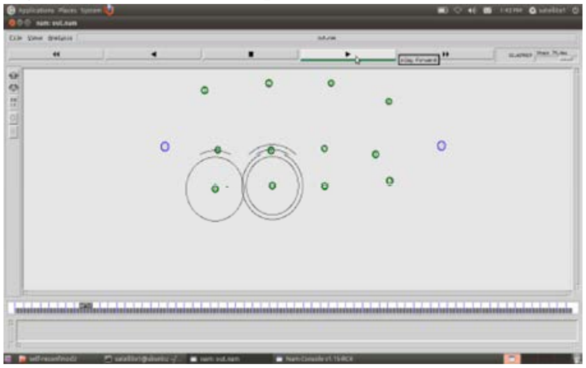

Fig. 20: Transmission of packets via Route 3

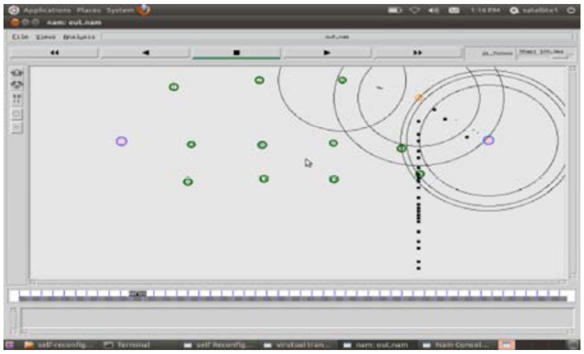

Fig. 21: Link failure in Route 1

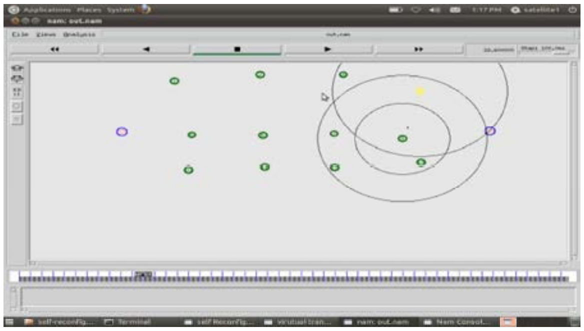

Fig. 22: ARS implementation to find alternate path

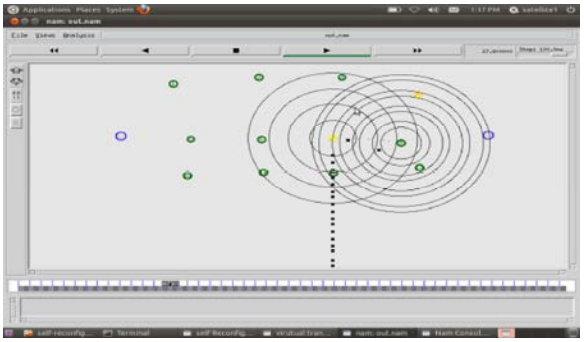

Fig. 23: Link failure in alternate path

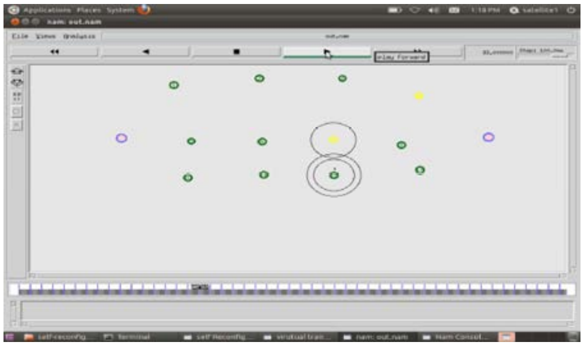

Fig. 24: ARS implementation in alternate path

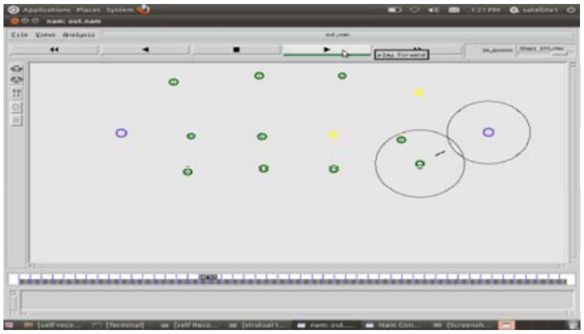

Fig. 25: Successful transmission of packets

Graphs: The graph and table shows the comparison of all three methods of data transmission in link failure is occurred [9].

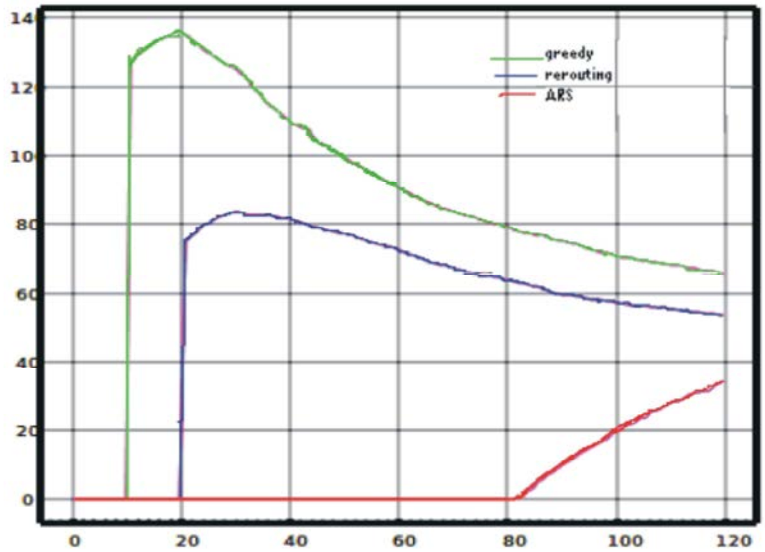

Fig. 26: Throughput Before Link Failure

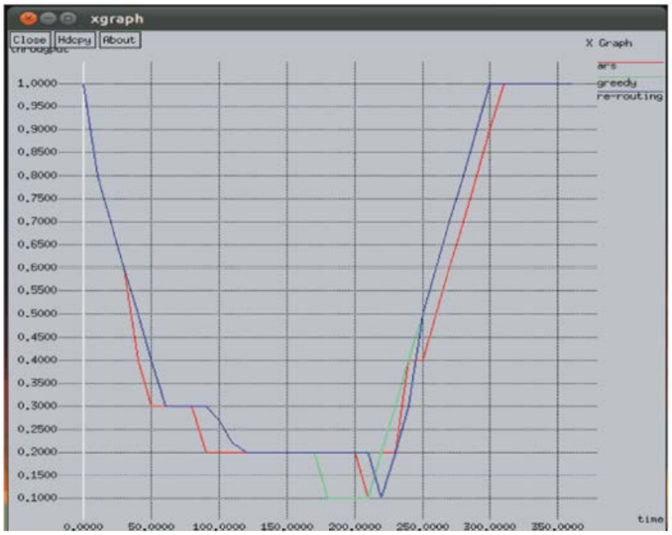

Fig. 27: Throughput After Link Recovery

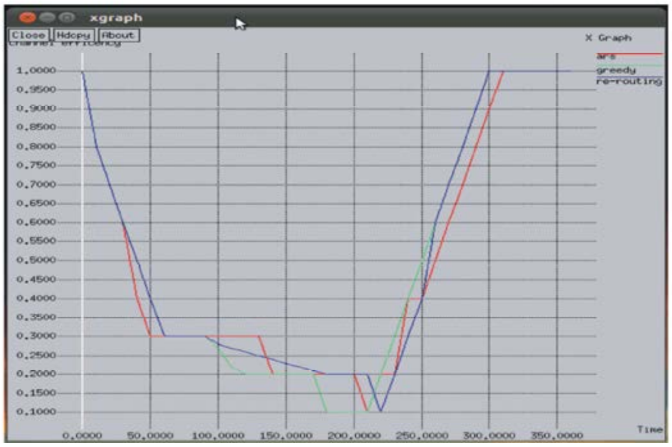

Fig. 28: Channel Efficiency

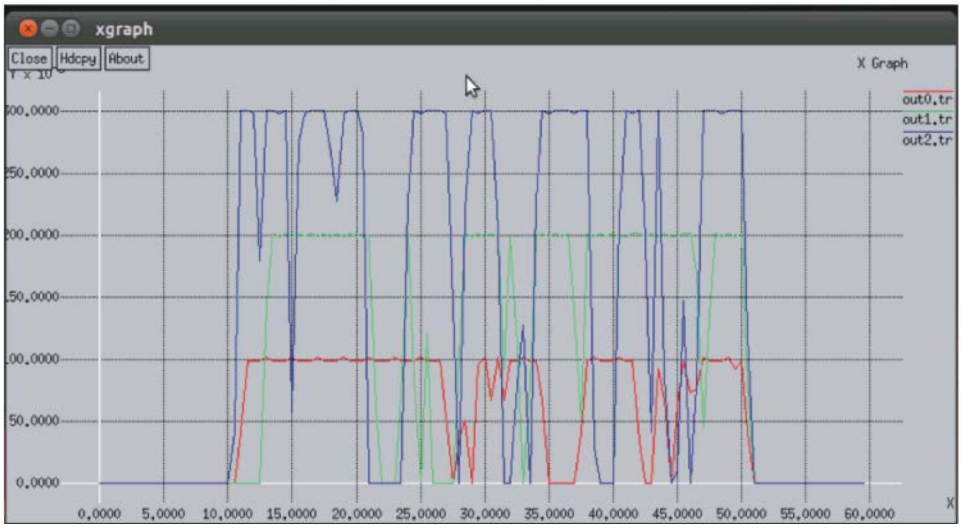

Fig. 29: Hop count

Table 1: Numerical Represenatation of Graph

Parameter	Greedy Algorithm	Local Rerouting	ARS
Throughput	30.25%	55.60%	75.0%
Efficiency	45%	60%	92%

CONCLUSION

As seen from the above graphs, we can conclude that ARS generates an effective reconfiguration plan that requires only local reconfiguration changes, radio and path diversity. ARS identifies reconfiguration plans that satisfy QoS constraints, admitting up to two times more flows than static assignment, through QoS planning. ARS's online reconfigurability allows for real-time failure detection and network reconfiguration, thus improving channel efficiency by 92%.

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