Self-Healing and Optimizing Adhoc Routing

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***Abstract* — Wireless networking is an emerging field with its potential applications in extremely unpredictable and dynamic environments. Individuals and industries choose wireless because it allows flexibility of location, whether that means mobility, portability, or just ease of installation at a fixed point. Wireless networks that fix their own broken communication links may speed up their widespread acceptance. The challenge for wireless communication is optimized handling of unpredictable environment through which communications travels. Despite early problems in overcoming this pitfall, the newest developments in self-healing wireless networks are solving the problem. The changes made to the network architectures are resulting in new methods of application design for this medium. This paper presents an overview of self healing networks and a new scheme has been proposed that tries to heal the routing when a link failure occurs. The scheme can be incorporated into any adhoc on-demand unicast routing protocol. In this research work, the proposed scheme has been incorporated to AODV and observation is that the performance has been improved. The simulations have been carried over NS2 simulator with existing schemes and proposed scheme. Simulation results indicated that the proposed technique provides robustness.**

***Key Words* — AODV, MANET, Power, Routing, Self Healing**

I. Introduction

There is tremendous technological advance in producing small and smart devices. The number of embedded devices in appliances and vehicles is increasing at a rapid rate. Thousands of such devices can be used for applications[1] like: environmental data collection, weather forecasting, measuring toxicity levels at hazardous sites etc. It is a natural consequence that such devices work in a collaborative way. However, users carry around many such smart devices and they are not fixed in the sense of a desktop computer. Hence, there is a need for networking such mobile devices without any infrastructural support. There is a growing demand of using networks of mobile devices [2] anywhere and anytime. Cellular Phones and Internet provide some solution, but Cellular phones work with infrastructural support like mobile phone towers and satellite communication. This support comes at a cost like pre-registration with a mobile service provider etc. In many situations, the Internet may not be an efficient solution. For example, a collection of people trying to communicate in a hotel or conference hall or in disaster situations like flood, fire. Adhoc network provide a solution to these problems. An ad hoc network is a collection of autonomous nodes, which may move arbitrarily so that the topology changes frequently. In contrast to conventional wireless networks, the nodes in mobile ad hoc network communicate using wireless links without any fixed network infrastructure and centralized administrative support. A node can act both as a switching or routing node. The purpose of an ad hoc network is to set up a short-lived network for a collection of nodes. If all the wireless nodes are within the transmission range of each other, routing is easy. Every node can listen to all transmissions. However, this is not true in most situations, due to short transmission range. Hence, most ad hoc neworks [3] are multi-hop. A message from a source node must go through intermediate nodes to reach its destination. All nodes cooperate in delivering messages across the network. The term "self-healing" is drawn from the natural biological paradigm. Computer immunology [4] is a hot topic in system administration. It would be great to have our servers solve their own problems. System administrators would be free to work proactively, rather than reactively, to improve the quality of the network. This is a noble goal, but few solutions have made it out of the lab and into the real world. Most real-world environments automate service monitoring, and then notify a human to repair any detected fault.

Rest of the paper is organized as follows. Section II gives emphasis on self healing network, section III gives an idea of self healing technologies, proposed self healing routing scheme has been explained in section IV, simulations and results are discussed in Section V and conclusions are in last Section VI.

II. Self Healing Network

In developing broadband digital networks, a short service-outage such as a link failure or a node failure can cause a serious impairment of network services. It is due to the volume of network traffic carried by a single link or node. Moreover, the outage can stimulate end users to try to re-establish their connections within a short time. The retrials, however, make the problem worse because the connection establishment increases the traffic volume further. Fast restoration from a network failure becomes a critical issue in deploying high-speed networks. Self healing algorithms have been recognized as a major mechanism for providing the fast restoration. A self-healing system [5] should recover from the abnormal state and return to the normal state, and should start functioning as it was prior to failure. One of the key issues associated with self-healing networks is to optimize the networks

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while expecting reasonable network failures [6, 7, 8]. Self-healing network (SHN) [9] is designed to support transmission of messages across multiple nodes while also protecting against recursive node and process failures. It will automatically recover itself after a failure occurs. The problem of self-healing is in networks that are reconfigurable in the sense that they can change their topology during an attack. One goal is to maintain connectivity in these networks, even in the presence of repeated adversarial node deletion. Modern computer systems are approaching scales of billions of components. Such systems are less akin to a traditional engineering enterprise such as a bridge, and more akin to a living organism in terms of complexity. A railway over-bridge must be designed in such a way that, key components never fail, since there is no way for the bridge to automatically recover from system failure. In contrast, a living organism cannot be designed so that no component ever fails: there are simply too many components. For example, skin can be cut and still heal. Designing skin that can heal is much more practical than designing skin that is completely rigid to attack. Unfortunately, current algorithms ensure robustness in computer networks through hardening individual components or, at best, adding lots of redundant components [10]. A simple recovery cycle is denoted in figure 1.

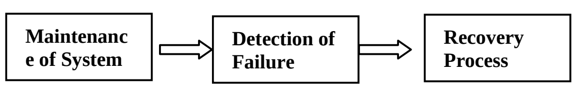


Figure 1: Self Healing Cycle

Critical issues [11] in self-healing systems typically include maintenance of system health, recovery processes to return the state from an unhealthy state to a health one.

Self-healing components or systems typically have the following characteristics [11]: (a) perform the productive operations of the system, (b) coordinate the activities of the different agents, (c) control and audit performance, (d) adapt to external and internal changes and (e) have policies to determine the overall purpose of the system.

Most of the self-healing concepts are still in very early stages; still some possible areas explored are Grid computing, software agents, middleware computing, ad hoc networks. Emphasis here is on ad hoc network self healing characteristic. Thrust areas considered are:

A. Self Healing in Routing

The most promising developments in the area of self-healing wireless networks are ad hoc networks. They are decentralized, self-organizing, and automatically reconfigure without human intervention in case of broken links. Automated network analysis through link and route discovery and evaluations are the distinguishing features of self-healing network algorithms. Through discovery, networks establish one or more routes between the originator and the destination. Through evaluation, networks detect route failures, trigger renewed discovery, and in some cases; select the best route available for a message. Because discovery and route evaluation consume network capacity so these two must be used carefully to achieve good network performance.

B. Self healing in RF

Environmental radio-frequency (RF) [12] "noise" produced by powerful motors, other wireless devices, microwaves and even the moisture content in the air can make wireless communication unreliable. Despite early problems in overcoming this pitfall, the newest developments in self-healing wireless networks are solving the problem by capitalizing on the inherent broadcast properties of RF transmission. The changes made to the network architectures are resulting in new methods of application design for this medium.

C. Self healing in Power Efficiency

As the network is always on, conserving power is more difficult. One solution is On-demand discovery **[**12**].** It establishes only the routes that are requested by higher-layer software. On-demand discovery networks are only "on" when called for. This allows nodes to conserve power and bandwidth and keeps the network fairly free of traffic. Once routes have been established, they must generally be maintained in the presence of failing equipment, changing environmental conditions, interference, etc. This maintenance may also be proactive or on-demand. Another solution can be Single-path routing [12**].** As for routing, network algorithms that choose single-path routing, single out a specific route for a given source-destination pair. Sometimes, the entire end-to-end route is predetermined. Sometimes, only the next "hop" is known. The advantage of this type of routing is that it reduces traffic load, bandwidth use, and power use. If only one node at a time needs to receive the packet, others can stop listening after they hear that they're not the recipient.

III. SELF-HEALING TECHNOLOGIES

Some of the self healing technologies for ad hoc networks are DSR, AODV, TORA etc**.**

*A. Dynamic Source Routing (DSR)***:** DSR uses dynamic source routing [13] and it adapts quickly to routing changes when host movement is frequent, however it requires little or no overhead during periods in which host moves less frequently. Source routing is a routing technique in which the sender of a packet determines the complete sequence of nodes through which to forward the packets, the sender explicitly lists this route in the packet's header, identifying each forwarding hop by the address of the next node to which to transmit the packet on its way to the destination host. The protocol is designed for use in the wireless environment of an ad hoc network. Route cache is maintained to reduce cost of route discovery. Route Maintenance is used when sender detects change in topology or source code has got some error. In case of errors sender can use another route or invoke Route Discovery again. The DSR is single path routing.

B. Temporary Ordered Routing Algorithm (TORA) [14]:

It uses the Link reversal technology. It is structured as a temporally ordered sequence of diffusing computations; each computation consisting of a sequence of directed link reversals. It is based on LRR (Link reversal routing). The protocol is highly adaptive, efficient, loop free and scalable. Important concept in its design is that it decouples the generation of potentially far-reaching control message propagation from the rate of topological changes. It reduces energy consumption without diminishing the capacity or connectivity of the network.

C. Ad hoc On demand Distance Vector (AODV) [15]:

It is pure on demand routing system The AODV routing protocol is intended for use by mobile nodes in an ad hoc network characterized by frequent changes in link connectivity to each other caused by relative movement. It offers quick adaptation to dynamic link conditions, low processing and memory overhead, low network utilization, and establishment of routes between sources and destination which is loop free at all times. It follows quick adaptation to changes. It has low memory overhead.

IV. Proposed Self Healing Routing Protocol

A new scheme has been introduced here to modify AODV to make it more self healed network protocol**.** The proposed scheme takes care of on demand routing and also power features. It uses a new concept of virtual nodes. Virtual nodes (VN) are nodes at the one hop distance from its neighbor. These virtual nodes help in reconstruction phase in fast selection of new routes. Selection of virtual nodes is made upon availability of nodes and their power status. Each route table has an entry for its power status (which is measured in terms of Critical, Danger and Active state) and number of virtual nodes attached to it. Whenever need for a new route arises, check for virtual nodes are made, their power status is checked and a route is established. Same process is repeated in route repair phase. Route tables are updated at each Hello interval as in AODV with added entries for power status and virtual nodes.

Some work already have been done on using multiple routes approach in ad hoc network protocols; the scheme by Nasipuri and Das [16], Temporally-Ordered Routing Algorithm (TORA) [14], Dynamic Source Routing [13], AODV [15] and Routing On-demand Acyclic Multi path (ROAM) [17], but these algorithms require additional control message to construct and maintain alternate routes.

More recent developments are based on Direction Forward Routing (DFR) [18]. When an update is received, a node records the "geographical direction" to where the update came from. When "predecessor" forwarding fails, the packet is forwarded to the "most promising" neighbor in the recorded direction. It is good for denser mediums only. Another change is Admission Control enabled On demand Routing (ACOR) [19]. In this a route with QoS requirements is created on-demand.

The proposed routing scheme is designed to heal for mobile ad hoc networks having link failures, with large number of nodes. It can handle low, moderate, and relatively high mobility rates. It can handle a variety of data traffic levels. There are two main phases in this protocol: REQ (Route Request) phase, REP (Repair Phase).

A. Route Construction (REQ) Phase

The proposed scheme uses AODV as base protocol. The scheme does not require any modification to the AODV's REQ (route request) [15,21] propagation process. Only change is in Route Table entry where two additional entries are made for VN and Power status.

B. Route Error and Maintenance (REP) Phase/Local Route Repair

Data packets are delivered through the primary route unless there is a route disconnection. When a node detects a link break, it performs a one hop data broadcast to its immediate neighbors. The node specifies in the data header that the link is disconnected and thus the packet is candidate for alternate routing. Upon receiving this packet, previous one hop neighbor starts route maintenance phase and constructs an alternate route through virtual nodes by checking their stability and power status.

Route Recovery involves finding VN, their power status, invalidate route erasures, listing affected DEST, valid route update, new route (in worst cases). The Time to Live (TTL) of REQ should initially be set to the following value from equation (1).

TTL = (Min TTL+ VN attached + Power status) ---(1)

where Min TTL is the number of hops to reach destination from said node. Power status is checked from route table, VN attached is the number of virtual nodes attached.

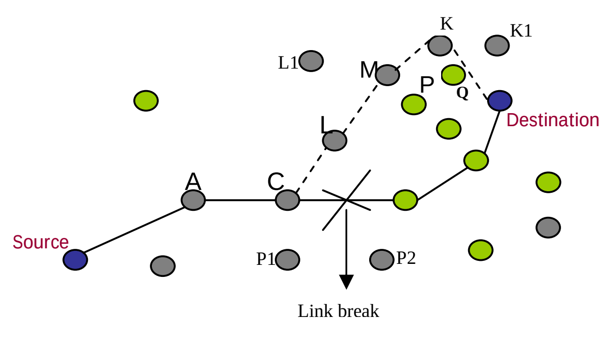


Figure 2: Local Repair

Figure 2 gives an idea of working of local route repair. Initial path from source node 'Source' to destination node 'Destination' is shown via solid lines. Active nodes are in black shade and nodes in danger level are in green shade. When link breaks at node C, route repair starts, node C starts searching for new paths, buffering packets from S-A in its buffer. Node C invokes Route Request phase for

'Destination'. Now virtual nodes are selected and proper selection of nodes is done based on power factor. Path selected becomes **[C - L – M – K – Destination],** instead of **[C – L – P –Destination],** since the node P is not in active state. Even though the route may become longer, but the selected route path is far more stable and delivers more packets. Stability of route depends upon two major aspects as: Life time and Power status. Repair attempts are often invisible to the originating node.

Table 1: Active Life Time Estimations

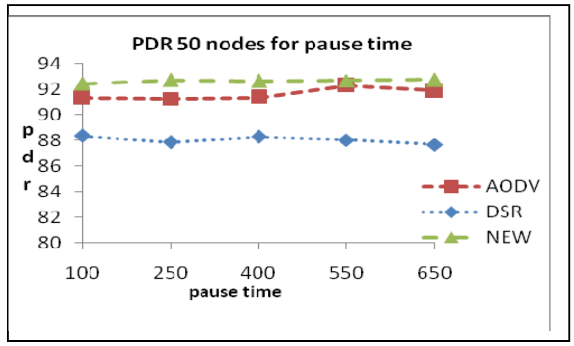
Node	VN	MinTTL	Power Status	**Total**
L =	3	3	9	15
M=	4	2	8.5	14.5
K=	3	1	8	12
P=	3	1	4	8
Q=	3	1	3	07
P1=	1	4	7	12.5
P2=	2	3	7	12
K1=	2	1	7.5	10.5
L1=	1	3	8.0	12

In AODV, a route is timed out when it is not used and updated for certain duration of time. The proposed scheme uses the same technique for timing out alternate routes.

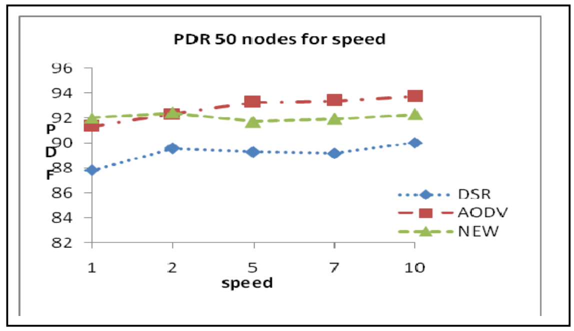
V. Simulation and Results

Simulation study has been carried out to study the Performance study of existing different protocols. Simulation Environment used for this study is NS 2.34 [20]. For realistic environment, power status has been widely distributed in the range of 3 to 10 for nodes. Range of 8-10 is safe, 4-7 is critical and 1-3 is danger mode.

Same scenario has been setup for 50 nodes in an area of 1KM×1KM. Packet delivery ratio has been observed by varying pause times from 0 to 650 and the speed has been changed form 1 meter per second to 10 meters per second. Scheme has been studied for both UDP and TCP connections in the same scenario generated with similar number of connections. Simulation results have been compared with other existing self healing techniques like AODV, DSR. Some efforts were made to include TORA in this study but efforts went in vain for TORA as it was not possible to attach energy model to TORA successfully, work is still in progress in this regards.

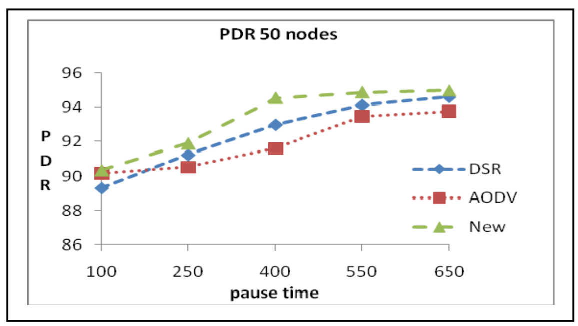


Graph 1: Packet Delivery Ratio using TCP connections with Pause time



Graph 2: Packet Delivery Ratio using TCP connections with Speed

Packet Delivery ratio obtained of a Scenario generated for 50 nodes, having 16 TCP connections with Pause time and speed as functions have been shown in Graph 1 and Graph 2 respectively.



Graph 3: Packet Delivery Ratio using UDP connections with Pause time

Simulations reveal that the proposed scheme tagged as 'New' gives better packet delivery ratio in all cases. In case of Pause time, the delivery is almost consistent for all schemes. AODV touches 92 to 93% mark all the time, 'New' has better results and is ahead in all cases. In case if increasing speed the delivery is bound to fall, still after initial hiccups 'New' takes lead even when speed is as high as 10 meters per second.

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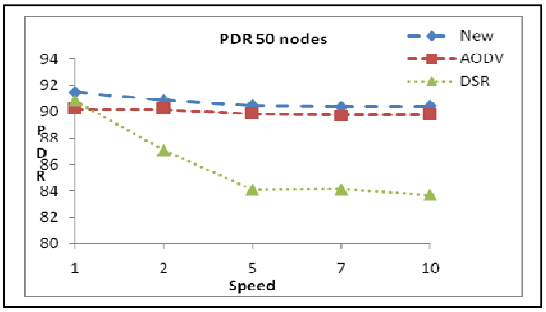
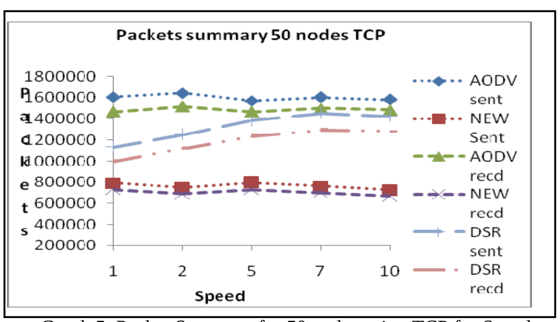


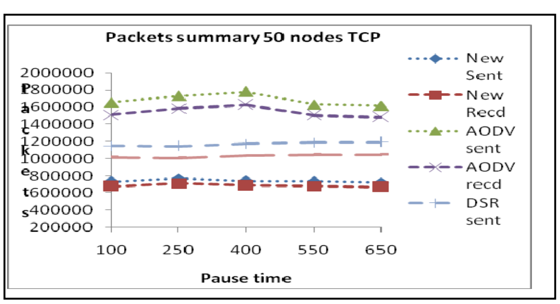
Graph 4: Packet Delivery Ratio using UDP connections with Speed

Packet delivery ratio experiment was repeated with same nodes and same connections using UDP instead of TCP connections. In case of Pause time DSR performance is better than AODV, this is contrary to other case of speed, where AODV outperforms DSR. The reason is still under consideration and more extensive checks are on for the scenario under study. In all cases the proposed scheme 'New' performs better, which further proves the scheme as better than others. The trend shows that proposed scheme is able to find stable routes using concept of virtual nodes and power status of nodes.

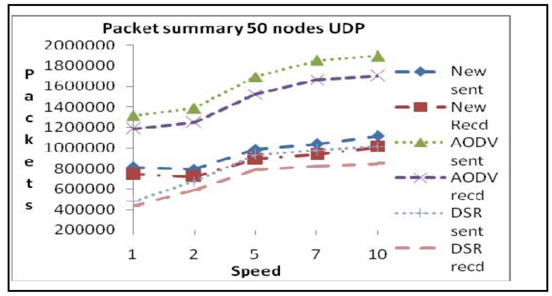
The experiment was repeated with another parameter as number of packets sent and received in all cases. The results are depicted in graph 5 and 6 for TCP connections and in Graph 7 and 8 for UDP connections. The results reveal that in case of TCP connections the maximum packets are sent and received by AODV. Numbers of packet sent by 'New' are less, it may be because of more calculations involved in initial phase when virtual nodes and power status is to be checked. Trend follows for UDP connections as well.



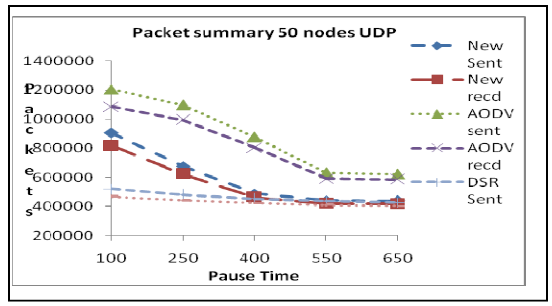
Graph 5: Packet Summary for 50 nodes using TCP for Speed



Graph 6: Packet Summary for 50 nodes using TCP for Pause Time



Graph 7: Packet Summary for 50 nodes using UDP for Speed



Graph 8: Packet Summary for 50 nodes using UDP for Pause Time

Efforts are on for performing simulations to calculate end to end delay and throughput for more evaluation purposes.

VI. Conclusion

In this paper a new scheme has been presented that tries to heal the routing when a link failure occurs. The scheme can be incorporated into any ad hoc on-demand unicast routing protocol. To avoid overhead, proposed scheme uses alternate routes only when data packets cannot be delivered through the primary route. As a case study, the proposed scheme has been incorporated to AODV and it has been observed that the performance improved. Simulation results indicated that the technique provides robustness. Study is going on currently investigating ways to make this new scheme robust to traffic load. The scheme takes care of power factor which improves the performance of scheme and provides healing by selecting power stable nodes. It was found that overhead in this protocol was slightly higher than others, which is due to the reason that it requires more calculation initially for checking virtual nodes and power checks. This also caused a bit more end to end delay. The proposal is to check this scheme for more detailed and realistic channel models with fading and obstacles in the simulation. Self-healing systems are relatively new both for the academia and the industry. However, hope is to see a large number of systems, software and architectures very quickly in future. Making the technology based on self healing concept will help in creating adaptive systems that provide functionality despite the possibility of disasters.

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