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EXECUTION EXPERIENCE WITH MANET ROUTING PROTOCOLS

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ABSTRACT

This paper plots our involvement in the implementa-tion and arrangement of two MANET directing conventions on a ve hub, four jump, organize. The work was provoked by the absence of distributed outcomes concerning the issues associated with the execution of MANET directing proto-cols on genuine remote systems, rather than aftereffects of recreation tests. We analyzed executions of two separation vector MANET steering conventions and found various issues with the two conventions over the span of our tests. The most signi cannot was that neither one of the protocols could give a steady course over any multi-bounce arrange association. The course disclosure procedure of the two conventions is tricked by the transient accessibility of system connects to hubs that were more than one jump away. Bundles transmitted over a blurring channel influence the steering convention to close mistakenly that there is another one bounce neighbor that could give a lower metric (jump tally) course to significantly increasingly far off hubs. This can happen in any event, when hubs are stationary, portability came about in even less course soundness. We executed a straightforward sign quality based neighbor se-lection method to test our attestation that blurring channels and inconsistent system joins were the reason for the disappointment of the directing conventions. The outcome was that neighbor discovery and the ltering for neighbors with which hubs could convey dependably empowers the production of solid multi-bounce courses. In light of our encounters, we layout a few suggestions for future work in MANET look into.

1. INTRODUCTION

The term pervasive figuring was authored by Mark Weiser to depict a condition of registering wherein clients are never again mindful of calculation being done [28]. The development of keen situations, where gadgets are inserted pervasively in the physical world, has started numerous new research territories and speaks to a stage towards universal figuring. To this end, analysts have started to diagram intends to accomplish universal registering.
Versatile specially appointed system (MANET) directing conventions assume a key job in a potential fate of omnipresent gadgets. Current MANET business applications have for the most part been for military applications or crisis situations[25]. How-ever, we accept that examination into MANET steering proto-cols will lay the basis for future remote sensor net-works and remote attachment n-play gadgets. The test is for MANET steering conventions to give a correspondence stage that is strong, versatile and dynamic even with broadly fluctuating remote channel attributes and hub portability.

The paper examines our experience while executing and sending two separation vector MANET steering conventions. We analyzed both an open area usage of the Ad Hoc On-Demand Distance Vector (AODV) [21] directing convention and actualized our own adaptation of the Destination-Sequenced Distance Vector (DSDV) [20] steering convention. The decision of directing conventions was logically founded on what (little) was accessible at the time this work was done. The AODV execution was the unreservedly accessible MAD-HOC usage [15]. This usage depended on a previous draft of the AODV convention and incorporates some MAD-HOC specific augmentations. Where AODV is referred to right now mean the MAD-HOC implementation except if in any case expressed. At the time our work was completed this was the main open area MANET defeating convention usage that had a permit reasonable for our utilization and that we could find a good pace, and work on our system. Confronted with no other accessible open space code and hesitant to put together our work exclusively with respect to one convention execution we coded another option.

Various broad reproduction concentrates on different MANET steering conventions have been performed by different scientists [25][5][16][8][7]. Be that as it may, there is an extreme ailing in imple-mentation and operational encounters with existing MANET directing conventions. Past execution encounters in-clude remote Internet doors (WINGS) [11], implemen-tation of ODMRP [2], AODV usage by Royer et al. [24] and ABR usage by Toh et al. [27]. These examinations just featured execution issues speci c to the convention being utilized. By a wide margin the most broad implemen-tation study to date was led by Maltz et al. [17] in depicting their execution of DSR.

operational specially appointed system that is fit for conveying valuable information. We report a few intriguing ob-servations not announced somewhere else for the utilization of MANET conventions inside pico-cell conditions. It is beneficial noticing that this current paper's goal is to give an account of the show tional possibility of existing directing conventions and e orts un-dertaken to make a dependable specially appointed system. From multiple points of view this is a stage back towards principal issues and away from the MANET steering convention perspectives as a rule inspected in reproduction contemplates. Though reenactment concentrates generally report on execution measurements, for example, throughput, idleness and bundle misfortune this paper provides details regarding the principal issue of \do MANET directing conventions work". The appropriate response is yes yet, on account of the two separation vector conventions we ex-amined, just if the inborn inconsistent and transient nature of remote system joins are taken into account.Unlike past work, our work provides details regarding the experience of building an operational specially appointed system that is equipped for conveying helpful information. We report a few intriguing ob-servations not revealed somewhere else for the utilization of MANET conventions inside pico-cell conditions. It is advantageous taking note of that this current paper's goal is to provide details regarding the drama tional practicality of existing steering conventions and e orts un-dertaken to make a solid specially appointed system. From multiple points of view this is a stage back towards major issues and away from the MANET directing convention viewpoints for the most part analyzed in reproduction examines. While recreation concentrates regularly report on execution measurements, for example, throughput, dormancy and bundle misfortune this paper gives an account of the key issue of \do MANET directing conventions work". The appropriate response is yes be that as it may, on account of the two separation vector conventions we ex-amined, just if the characteristic temperamental and transient nature of remote system joins are considered.

This paper is sorted out as follows. In Section 2 we give a concise outline of AODV and DSDV. This is trailed by usage subtleties of both these conventions in Section

In Section 4 we portray the testbed utilized for our exper-iments. Segment 5 presents the issues and perceptions picked up from setting up the testbed and running the directing conventions over it. In Section 6, we present the activities of powerwave. In light of our involvement in MANET defeat ing conventions, we examine issues and issues experienced according to existing steering conventions and propose some future headings in Section 7. At long last, the ends are introduced in Section 8.

given goal address. Hubs that have a course to the goal react to the RREQ by sending a course answer (RREP) message to the source and record the course back to the source. Hubs that don't have a course to the des-tination rebroadcast the RREQ message in the wake of recording the arrival way to the source. In case of connection breakage a course blunder (RERR) message is sent to the rundown of hubs (re-ferred to as antecedents) that depend on the wrecked connection. Endless supply of a RERR message, the comparing course is in-approved and another RREQ might be started by the source to recreate the course [21]. An opportunity to-live (TTL) eld is utilized in RREQs for an extending ring search to control ooding. Progressive RREQs utilize bigger TTLs to build the quest for goal hub.

Not at all like AODV, DSDV [20] is a table-driven (or proactive) steering convention and is basically founded on the fundamental dis-tributed Bellman-Ford directing calculation [1]. Every hub in the system keeps up a steering table comprising of the following bounce address, directing measurement and arrangement number for every goal address. To ensure circle free activity, steering refreshes from a given hub are labeled with a mono-tonically expanding arrangement number to recognize stale and new course update messages. Hubs occasionally communicate their steering tables to neighboring hubs. Given su cient time, all hubs will merge on normal directing tables that rundown reachability data to every goal in the system. Course refreshes are created and communicated all through the system when hubs find broken net-work joins. Hubs that get a course update verify whether the arrangement number speci ed in the course update mes-sage is higher than the succession number recorded in their own steering table before tolerating the update. DSDV re-duces steering messages overheads by supporting both full and gradual updates of directing tables.

The primary quality of table-driven conventions is that a course to each hub in the system is constantly accessible re-gardless of whether it is required. This outcomes in considerable flagging overhead and force utilization [25].

Besides, table driven conventions transmit course refreshes paying little mind to organize load, size of steering table, transfer speed and number of hubs in the system [5]. Intrigued perusers are alluded to Toh et al. [25] for a subjective examination dependent on reproduction tries between avors of both on-request and table-driven directing conventions.

2.Directing PROTOCOL IMPLEMENTA TIONS

This segment presents usage subtleties of the AODV and DSDV conventions utilized in our trials and gives a foundation to the conversations and perceptions which will follow with respect to the sending and execution issues we have experienced**.**

2.1 MAD›HOC Implementation of AODV

The bundle catch program catches parcels that cross the system interface and triggers the aodv daemon when specific bundles are seen. The catch component is im-plemented utilizing the libpcap library [14]. Three sorts of parcels are of intrigue: address goals convention (ARP) bundles, Internet control message convention (ICMP) bundles and Internet convention (IP) bundles. Un-addressed ARP re-missions from a host demonstrate that a course to a given desti-country is required, bundle catch separates the goal IP address from the ARP parcel, and passes the location to the aodv daemon. aodv daemon at that point produces a course demand for the goal. At the point when an ICMP message is parsed parcel catch decides if the ICMP mes-sage got is of type ICMP DEST UNREACH, ICMP UNREACH HOST or ICMP UNREACH HOST UNKNOWN. In the event that the message coordinates the above ICMP types, the aodv daemon is noti ed of a connection breakage to a given goal address. All other ICMP messages are disregarded. At the point when a connection break is recognized, the aodv daemon gives a course mistake message to all hosts utilizing the wrecked connection. The source address of information parcels caught by bundle catch are passed straightforwardly to aodv daemon to refresh the course lifetime which the information parcels showed up on. The MAD-HOC AODV usage.

utilized hi messages, intermittent communicates, to keep up a neighborhood network list.

The principle issue with the MAD-HOC AODV implementa-tion was that bu ering was not performed while course con-struction was in progress. In down to earth terms, we saw that a telnet meeting had as started on numerous occasions before a meeting could be built up. When running ping over a four bounce course, with the default one second hole between succes-sive pings, the rst ve bundles were normally lost before the course was effectively settled.

2.2 DSDV Implementation

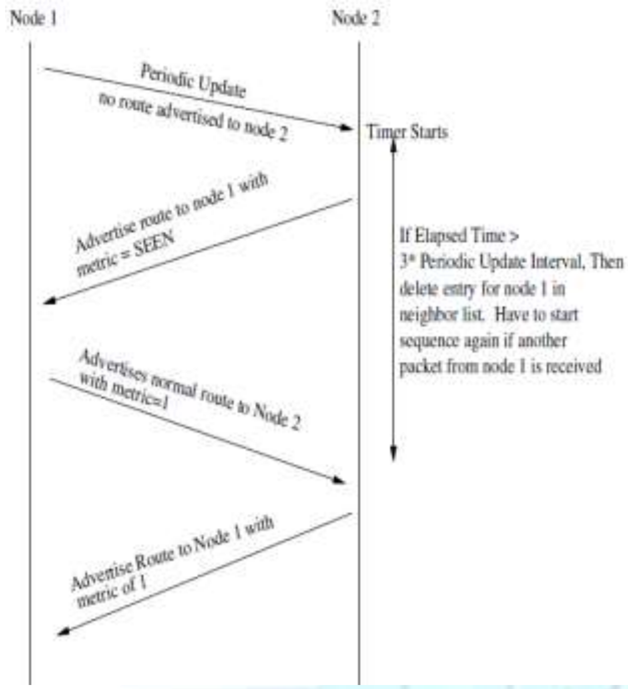
The second steering convention we decided to explore different avenues regarding was DSDV. The decision was made because of DSDV's straightforwardness, along these lines empowering us to effectively code up and troubleshoot the activity of DSDV on our testbed. DSDV's effortlessness demonstrated important during our experimentation particularly while clarifying the poor activity of DSDV on our testbed.

Our DSDV execution depended on the ACM SIG-COMM'94 paper by Perkins et al. [20] with the expansion of a neighbor handshake convention to check for bi-directional connections. Our DSDV execution utilized the Multi-strung Routing Toolkit (MRT) [19] for stage freedom and for interfacing with the part steering table, attachment and le input/yield (IO). Likewise, MRT additionally gave some advantageous information structures to holding data respect ing machine interfaces and utilities for controlling IP promotion dresses. Because of the little size of our testbed, the incre-mental update parts of DSDV were not actualized (all the courses could without much of a stretch t in the one bundle). The hysteresis clocks were likewise not actualized as we didn't have many backup courses of action of a similar jump tally.

2.2.1 The SEEN Metric and State

The first paper depicting DSDV [20] specified that DSDV expect bi-directional connections yet does exclude any mechanism for guaranteeing a connection was bi-directional before a course was set up. It was discovered that such a system was pivotal with blurring channels. We expanded DSDV through the incorporation of a handshake convention that utilizes the SEEN measurement to flag that another neighbor had been detected**.**

The SEEN metric was de ned as an integer value outside the range of one to INFINITY[2]. DSDV nodes advertise a route to a node with metric = SEEN on the reception of a packet from a neighbor for the rst time. All other nodes, apart from the node listed as the route destination, ignore this route. On receiving a routing advertisement for itself with a metric = SEEN a node makes and advertises a route to the sending node. Nodes will only advertise a route to another node with a SEEN metric for a short period of time, if no reciprocal route advertisement is received then the SEEN state times out and the route is no longer advertised. The signaling process used in the discovery of a bi-directional neighbor using the SEEN metric is illustrated in Figure 1.



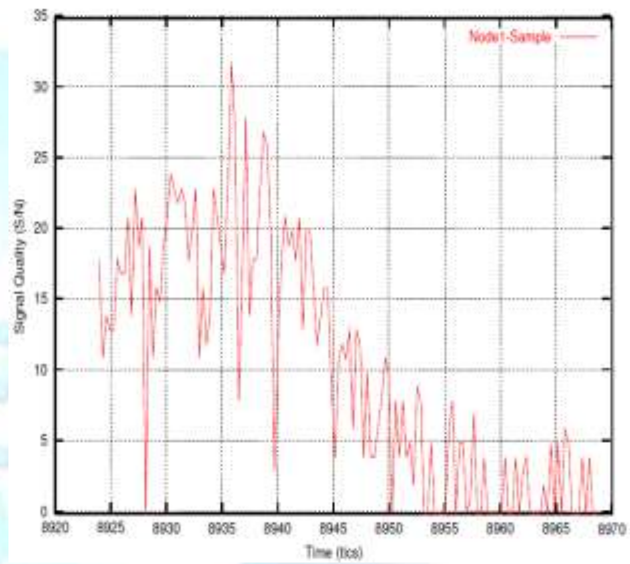
3. TESTBED

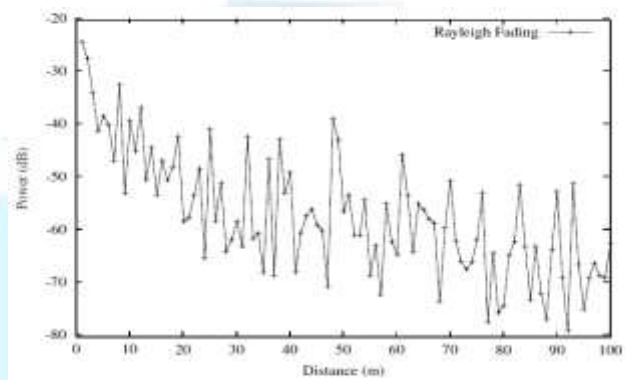
Figure 4 shows the network topology of our testbed. Our testbed consisted of two notebooks and three desktop com-puters, equipped with Lucent Wavelan IEEE 802.11b PCM-CIA cards and running Linux (Debian with 2.2.15 kernel). We used version 6 of the Linux driver from Lucent for the IEEE 802.11b cards, with the transmit rate set to 1 Mb/s.

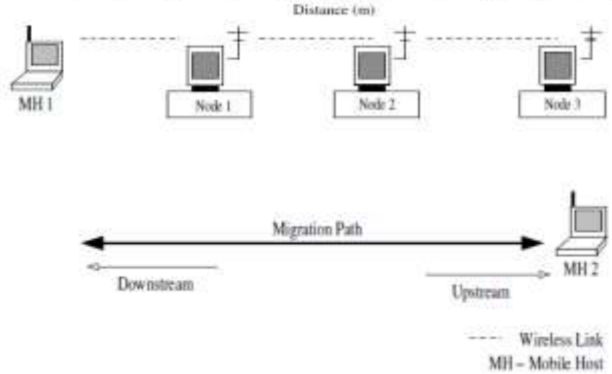
also, the activity mode set to advertisement hoc3 . The least channel rate was picked to keep away from the cards venturing down transmission rates naturally (an element that we couldn't other- savvy handicap). The cards were con gured to transmit on an in any case unused channel to keep away from obstruction from other IEEE 802.11b gadgets in our lab. To restrict the transmission go, we wrapped each card with a metallic enemy of static sack. Subsequently, we figured out how to drop the transmission extend from 250 meters to around ve meters. This empowered us to make a four jump arrange in our lab and keep away from the issue of finding the in a large eld.

Note that the counter static wrapping didn't modify the radio engendering attributes of an indoor of- ce condition comprising of delicate parcels. The watched radio engendering behavior,

i.e., Rayleigh Fading, of the testbed is steady with Hashemi [13]'s examination on indoor radio spread models. Figure 2 and 3 show a comparision- child of the sign to-clamor proportion as estimated on our testbed what's more, that of Rayleigh blurring separately. As can be seen, both test and theoritical model concurs, henceforth the hostile to static wrapping did not alter the fading behavior of the channel which adds to transient connections. Perusers who are keen on indoor radio spread models and Rayleigh blurring are alluded to [13] and [23].







to as upstream. In the subsequent analysis, we performed le moves (utilizing FTP) between M H1 and M H2 . In our tests no different meetings were available and the system tra c in our trials comprised completely of information move between the portable hubs and steering messages. Moving M H2 along the line of hubs practiced the versatile highlights of the directing conventions. The hubs were put with the end goal that M H2 should course parcels through each of node1, node2 and node3 thus as it is moved upstream. Each of the xed hubs was set so it could convey reli-capably with adjoining neighbors however couldn't send or get parcels dependably to the next progressively far off xed hubs.

4.EXPERIMENTAL OBSERVATIONS 5.1 4.1 Fading and Transient Network Links

It was discovered that transient radio connections brought about poor operation eration of both the steering conventions analyzed where no dependable courses could be built up. Poor people activity was because of the creation and upkeep of courses without taking the solidness, or quality, of the system joins com-prising the course into account. The central issue was that effective transmission of a datagram over a wire-less system connect is probabilistic, paying little heed to bring down level conventions. By and by this probabilistic e ect became ev-ident in two different ways; intermittent dropped parcels on a nor-mally \good quality" arrange connect and periodic effective bundle transmissions on an ordinarily \poor quality" organize interface. We found that the periodic dropped parcel didn't present quite a bit of an issue for both of the directing conventions analyzed. On a \good" arrange connect the connection layer acknowl-edgements in 802.11 supplanted lost unicast bundles and the directing conventions seemed, by all accounts, to be ready to deal with the occa-sional lost communicate, or multicast, parcel. Conversely the infrequent appearance of a channel between two hubs that couldn't ordinarily impart was troublesome to the defeat ing conventions on our testbed. The issue showed itself in the production of system courses that were not reasonable for the dependable transmission (and gathering) of client information. These courses were picked over other course alternatives by the conventions choosing for most reduced bounce courses, paying little mind to any kind of mea-certain about course quality. As expressed in the presentation a comparable e ect for the DSR directing convention has been seen on another testbed [18].

We found that it was for all intents and purposes difficult to set up a stable telnet meeting between hubs over a three or four bounce course on our testbed. For instance when utilizing the topol-ogy portrayed in Figure 4, we found that N ode1 could in any case identify N ode3 's signal incidentally in spite of cautious arrangement and direction. Therefore we saw that the two hubs would arbitrarily get a parcel from the other. In the event that AODV was occupied with a course constructing process it would utilize the un-solid one jump course from N ode1 to N ode3 in inclination to the two bounce elective. DSDV would supplant the current two jump course between the hubs with the inconsistent one bounce course. Next to no client information would be transmitted over this questionable course and client meetings would hang pending the restoration of the more solid two jump course.

In a related work, Maltz et al. [17] announced comparative be-havior while building a MANET testbed and exploring different avenues regarding Dynamic Source Routing (DSR) directing convention. The accompanying modi cations to DSR were proposed to survive

the issue of directing over temperamental connections: (1) screen course blunder on joins, (2) utilize the geographic situating sys-tem (GPS) to decide the neighbor vicinity (expecting physical nearness will give the best channel) and (3) consolidate GPS with course mistake observing. Unwavering quality was tried over a three hub, two jump coordinate with the hubs orchestrated in a line. The system included bundle ltering programming to keep parcels from being transmitted straightforwardly from one end hub to the next. They found that a FTP le move between the end hubs was progressively dependable when the parcel ltering programming was empowered. Ramanathan et al. [22] also announced issues with transmission extend when testing out their nature of administration (QoS) based directing star tocols. Be that as it may, no answers for problematic connections were sug-gested.

Distributed articles giving an account of MANET steering convention execution frequently depend on reenactment tests. Exper-iments run on our testbed revealed extensive di er-ence in the likelihood of effectively getting parcels on a MANET hub versus the likelihood of fruitful bundle gathering in some reproduction conditions. In a simula-tion condition, for example, ns-2 [10], it is commonly accepted that the likelihood of getting a parcel is e ectively one (pending impacts and so forth) and once a hub moves out of an-other hub's sign range, or a given separation, this drops to zero. Notwithstanding, our analyses have indicated this is un-practical; signals will in general rot gradually and there is no cuto point. We presume that the utilization of shortsighted radio propaga-tion models in MANET reproduction situations has prompted wrong evaluations of the exhibition of different defeat ing conventions, particularly those which use jump consider the prevailing course determination metric. In this way, one zone for future work is the consolidation of better radio proliferation models that help channel blurring and different contributions to the proba-bilistic nature of remote channels. For instance, Rappaport

lists various components that an ect blurring in an in-entryway condition, for example, multi-way spread, portable hub speed, encompass object speed and sign data transfer capacity.

5. Handoff in a MANET

In ordinary cell organizes, the sign to-clamor proportion (SNR) of the association between cell phone and base stations is observed to decide when to hand o starting with one base station then onto the next. In a MANET, current conventions don't foresee when a connection's SNR will fall underneath a limit. The occasional HELLO messages in AODV and course update clocks in DSDV are not used to envision hand o , they show nearness or nonattendance of a neighbor hub. Conse-quently, the course support process at both AODV and DSDV is just started after connection breakage as of now ocurred.

DSDV acts di erently relying upon the versatile hubs heading of development. DSDV master effectively changed to a lower bounce check course on the off chance that one was accessible, yet held tight to a course until it is expressly broken should a lower jump tally course not be accessible. The e ect with DSDV was smooth handover when M H2 (in Figure 4) was moving downstream yet no handover the upstream way.

The upstream way two things would provoke another (higher bounce check) course to be utilized. To begin with, the association with the past xed hub would need to break inciting.

a change to the following best accessible course being publicized by the new neighbor. Or on the other hand second, the connection between the past xed hub would need to break alongside a course adver-tisement being gotten from the new neighbor with a higher jump check and a higher succession number. The new grouping number would then discredit the old course and cause the new course to be utilized.

5.3 AODV Speci c Issues

5.3.1 Pico cell size and AODV's timers

An issue experienced were AODV's default parameters. Since the transmission scope of every hub was diminished in our testbed to under 5m, we had in e ect developed a system with pico estimated cells. Right now default MAD HOC AODV clocks superfluously drawn out course development and required tunning before an acknowledge capable presentation could be accomplished. The parameters we changed are recorded on Table 1. AODV's parameters as spec-I ed in [21] are left to the practitioners, anyway ongoing drafts have utilized more preservationist parameters than those in the MAD-HOC usage appeared in Table 1.

BCAST ID SAVE is utilized to forestall over ooding of RREQ messages. At the point when another RREQ is blocked, the informa-tion inside the RREQ is recorded and the data is added to an interim line alongside a period interim (mutt lease time in addition to BCAST ID SAVE). In case of another RREQ showing up inside this time interim, the RREQ is disposed of.

RREQ RETRIES limits the quantity of RREQs for a given goal. The default esteem is two. We saw this incentive as excessively moderate, and found that ve was more appro-private esteem.

Dynamic ROUTE TIMEOUT is utilized to decide the life-time of a given course. The lifetime of each course kept up by a given hub is revived in the wake of watching information bundles or HELLO messages on that course. In a pico-cell condition, the default esteem should be little. In our testbed where hubs moved at moderate strolling pace, the ideal opportunity for a hub to navigate given cell was around ve and we found a course break estimation of one second was suitable.

Both NODE TRAVERSAL TIME and NET DIAMETER must be modi ed to suit our system topology. The NODE TRAVERSAL TIME was modi ed to build the course con-struction time. The default estimation of NET DIAMETER was set to 35 hubs and this was changed to ve to reect the quantity of hubs in our testbed.

The last parameter to be modi ed was ALLOWED HELLO LOSS which decides what number of HELLO messages are lost before a connection is viewed as broken. Courses were timing out much of the time in our testbed and we set the ALLOWED HELLO LOSS parameter to ve to expand security.

The advancement of AODV by changing the parameters to suit our testbed was done on an experimentation premise. To date there are no distributed rules or heuristics for setting AODV's parameters or adjusting them to a given system. The parameters appeared in Table 1, and the other AODV dad rameters that have been de ned in the AODV speci cation.

5.3.2 ARP Interactions

The dependence of the MAD-HOC AODV execution on sni ng ARP bundles to flag the requirement for course construc-tion prompted two issues. The rst issue was that bundles were not bu ered while the course was being constructed. As men-tioned in Section 3 this prompted

Table 1: MAD-HOC's AODV Parameters

bundles being dropped and the need to begin an application, for example, telnet various occasions before a course was really fabricated. The second prob-lem was that a course will never be built if there is a passage in the ARP reserve. Deceptive ARP store sections exist for at least one reasons. Either the two hubs being referred to had once been adjoining, and the ARP store section still couldn't seem to break, or an ARP answer was un-expectedly got from a remote hub (over a problematic connection) and the reserve at that point forestalled an increasingly solid course being found.

Parameters	Default Values	New Values
BCAST ID SAVE	30000ms	3000ms
RREQ RETRIES	2	5
RREP WAIT TIME	(3 NODE TRAVERSAL TIME NET DIAMETER)=2	No Change
NODE TRAVERSAL TIME	100ms	10ms
NET DIAMETER	35	5
ACTIVE ROUTE TIMEOUT	9000ms	1000ms
ALLOWED HELLO LOSS	2	5

One work around to these issues was to normally ush the ARP reserve and to begin applications on numerous occasions while sitting tight for the course fabricating procedure to finish. In prac-tice this would be reachable by utilizing ping and hanging tight for a fruitful answer before beginning the expected application. A superior arrangement is the one proposed in [24] that utilizes a netlink attachment to convey steering data with the portion space and a spurious course for bu ering information bundles pending course development.

5.4 DSDV

5.4.1 *Route Stability*

The rst thing we saw about our DSDV implementa-tion was its relative security contrasted with the MAD-HOC's AODV usage. DSDV was less an ected by unreli-capable associations with far off hubs. This was principally because of the utilization of the SEEN measurement (requiring a handshake before the connection would be utilized in courses) and less communication with the ARP store as the directing table was pre-populated with have courses (nullifying the need to ARP).

Anyway DSDV was antagonistically an ected by transient connection profit capacity. In any event, when all the system hubs were stationary the directing table would gradually "beat" as courses were con-structed to far off hubs and afterward break

6. SIGNAL QUALITY BASED NEIGHBOR SELECTION

Our perceptions/tests indicated that the primary inadequacy with both AODV and DSDV to be an inability to deal with the surprising accessibility of a channel to a far off hub. The ensuing utilization of one bounce connects to inaccessible neighbors brought about questionable courses over which next to no client level information could be sent. The reason for this issue was the disappointment of the steering approach deamons in every hub to di erientiate among \good" and \bad" one bounce neighbors. We hypothe-sized that if hubs could lter for solid one jump neighbors and utilize just these neighbors as next bounce portals, the re-sultant courses ought to be dependable

To confirm our speculation we executed a neighbor selec-tion dependent on signal quality (called powerwave). We found that its utilization brought about solid multi-jump associations on our

6.1 Signal Based Route Selection

developed to be transparent to the routing protocol and used packet ltering to block routing messages from neighbors deemed unreliable. With neighbor selection we wanted to identify nodes one hop distant to which packets could be reliably sent and and make these available to the routing daemon Operating as a sublayer beneath the routing protocols as-. sisted routing protocols in selecting routes over reliable net - work links. Our aim was to provide a generic neighbor dis- covery framework that we could use to test implementations of MANET routing protocols.

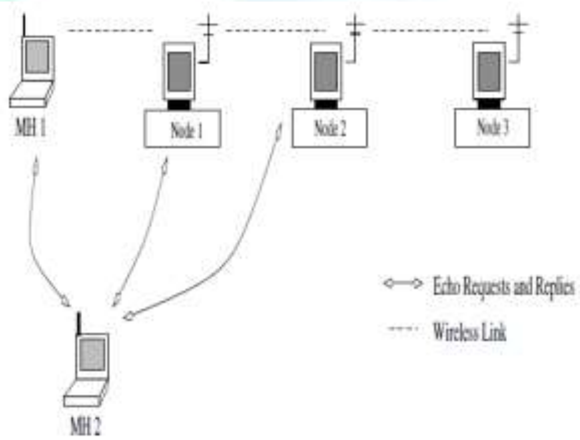
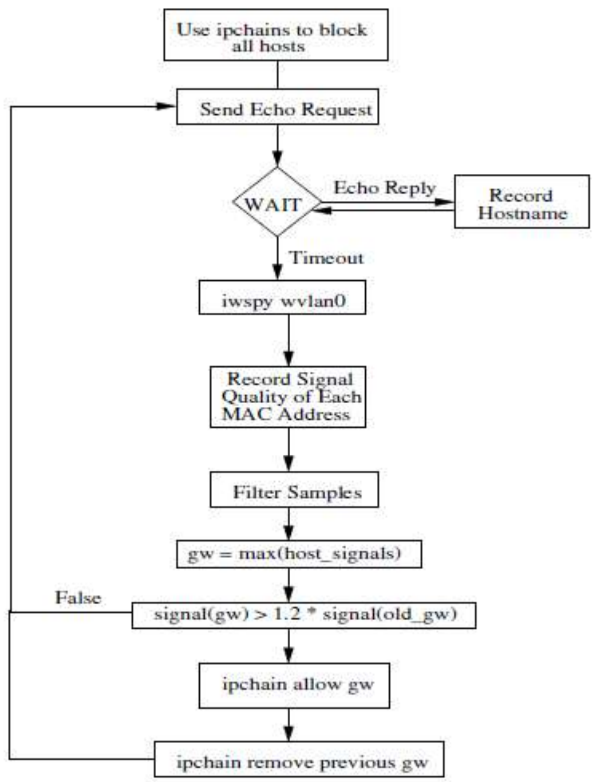
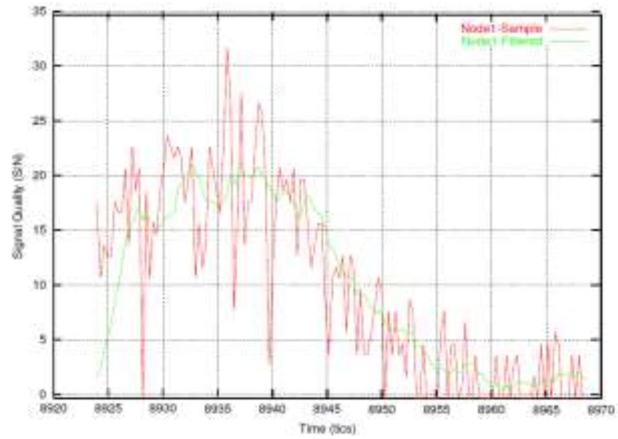


Figure 6 shows the workings of our **powerwave** program on the mobile node. The value 1.2 was derived from measur-ing the signal strength on our testbed and determining an appropriate threshold that constitutes good signal strength. Before the program starts, the following **ipchains** rule is ex-ecuted to lter out all messages (for AODV): ipchains -A input -p udp -d 255.255.255.255 1303 -s 0.0.0.0 -j DENY

After the ipchains rule has been executed, echo requests were broadcasted and the SNR of replies were gathered. The sig-nal strength associated with each link-layer address was then recorded and averaged. Averaging was required due to the random nature of a single SNR sample. Figure 7 shows raw SNR samples versus a moving average. The 'best' gateway



to route packets through was calculated based on previously recorded signal quality compared to current signal quality for each responding node. Note that the signal qualities used for comparison were averaged values. We tried using a xed threshold value (20 dB) to determine the change of gateway. However, we found that due to the varying signal quality from multiple nodes, the choice of gateway tended to uctuate frequently. Simply using a threshold value on the received signal quality was not e ective and we found it did not yield reliable routes. Once the best gateway to route packets through was found, the following **ipchains** rule was executed (for AODV) to allow HELLO messages from the gateway:



stationary nodes in our testbed[5]. To ensure reliable links to their neighbors and more importantly to lter out HELLO messages from M H_2 that were transmitted over unreliable links. The reasons why **powerwave** was required on the static nodes were as follows. During route construction, a node downstream may have a shorter hop count, due to HELLO messages from M H_2, hence a RREP would be returned di-instead of being routed through the desig-nated gateway. Since M H_2 ignores RREP messages from all nodes except for the designated gateway, M H_2 would then conclude that a route to M H_1 was impossible, resulting in the cancellation of the route construction process.

Powerwave programs running on stationary nodes required the following modi cations: **Ipchain rules**. In the static nodes, speci c rules were used to block out HELLO messages from non-neighboring nodes. For example, N ode_2 (from Figure 4) only needs to listen to N ode_1 and N ode_3 . The corresponding **ipchain** rules used to block out the appropriate nodes on N ode_2 (for AODV) were

```
# Clean everything out
# Clean ipchains –F
# Default deny ipchains -A input -p udp -d 0/0 1303 -j DENY
ipchains –I  input 1 -p udp -s node1 –dport 1303 –j ACCEPT
ipchains –I input 1 -p udp -s node3 –dport 1303 –j ACCEPT
#  Set up rule to be replaced blocking AODV from mobile ipchains -I input
   1 -p udp -s 10.1.0.100 --dport 1303 -j DENY ipchains -L
```

The **ipchains** con gurations shown above are static which is unrealistic in a MANET where all nodes may move. However, the above rules can be adapted easily.

The **powerwave** program su ers from two shortcomings: (1) ine cient bandwidth consumption, and (2) ine cient in-teraction with AODV and DSDV. In the rst case, **pow-erwave** on M H_2 broadcasts a continuous stream of echo messages in order for it (and other nodes) to measure the signal strength of packets received from each node. This in-creases contention time of other nodes wishing to transmit thereby reducing throughput of the network. In the second case, **powerwave** relies on blocking of HELLO messages from \bad" neighbors. Merely blocking routing messages leaves detection of broken links to the protocol timers. In future revisions, **powerwave** will signal the loss of a neighbor and also the appearance of a new neighbor directly to the rout-ing protocol. Thereby routing protocols can be made aware of link-breakages and new neighbors in a timely manner.

While AODV and DSDV choose routes based on hop count, there are some MANET routing protocols such as SSA [9] that choose routes based on signal quality. Our experience with **powerwave** showed that a signal quality based routing protocol has to incorporate some form of stability metric after a route has been established to avoid the transfer of route as soon as a better signal link becomes available.

A similar approach to **powerwave** was also taken by Maltz et al. [18] where a program called **mac lter** was developed to lter out tra c from unwanted MAC addresses. A novel usage of **mac lter** was the emulation of a MANET where multiple nodes could be placed closely together and the sig-nals from neighboring nodes ltered appropriately to give a di erent topology. The main di erence between **mac lter** and **powerwave** is that **powerwave** uses SNR to dynamically determine which IP addresses to lter out whereas **mac lter** is statically con gured for the topology in question.

An interesting conclusion from Matlz et al.'s work was that they found neighbor selection to be important [18]. Our work further reinforces this believe, and we envisage more research work in the development of neighbor selection in MANET research.

7. DISCUSSIONS AND FUTURE WORK

7.1 Unstable Links

The majority of MANET routing protocols described in the literature were designed to handle topology changes and do not take unreliable links into account. Currently, only sig-nal stability based adaptive routing (SSA) [9], ABR [26], and longest life routing protocol (LLRP)[29] support the notion of reliable routes. The route metrics use by SSA are average signal strength and route stability. By using these route metrics, packets will always be routed through the most reliable route (possibly closest node). Thereby route reconstruction cost is reduced and reliability of established route increases [9].

Unlike SSA, ABR only use route stability as the routing metric. Route stability is de ned as the number of HELLO messages observe from a given neighbor. Hence, a neighbor with a given HELLO message count is considered stable. In both SSA and ABR, the destination has to choose the best route to take from a number of alternatives recorded from the various route requests received [29]. Further, once a route is setup there are no considerations for degraded links along the route. Routes are only rebuilt once they are broken.

The immediate future work is to re-evaluate existing hop based routing protocols with the addition of unreliable links

7.2 Smooth Handoff

Data The notion of smooth hando in MANET routing proto-cols has generally been overlooked. Improvements may be made by intelligently monitoring surrounding neighbors and determining whether a given node is able to prime an up-stream/downstream node with a route to the destination.

We found that a relatively smooth handover could be achieved by generating regular RREQs from M H_2. In other words, when a node detects a new neighbor a special message could be sent to prime the new neighbor, with routes to other new receiver nodes without waiting for existing routes to break.

Pro-active route construction will cause unnecessary tra c and duplicate routes which may then lead to the di culty of removing invalidated routes. Further, the problem becomes more complicated if mobility is taken into account. Unlike traditional one hop wireless networks (e.g., cellular) where base-stations are xed, the hando decisions in MANETs are much more complicated.

It is interesting to note that the **powerwave** neighbor selec-tion process had the side-e ect of enabling a degree of hand-o . The neighbor selection process ltered out neighbors be-fore the network link disappeared entirely. User datagrams could still be forwarded over the link while the routing pol-icy engine was nding a new route. It worked in our imple-mentations because the routing parameters and the rate at which M H_2 moved matched.

7.3 Topology Dependent Parameters

Our experiments showed that the protocol parameters in both MAD-HOC's AODV and DSDV required some tun-ing before they would work properly. The determination of suitable timer values depended on channel rates, network topologies and mobility patterns [8]. The impact of these parameters on the performance of upper layer protocols is left for future work.

One method to allow for adaptive parameters is to intro-duce additional information. Protocols may rely on GPS, for example location aided routing protocols, to gather more information such as network topology and nodes proximity. Once the range of adjacent nodes are estimated, parameters may be adjusted accordingly.

7.4 Neighbor Selection Sub›Layer

The Internet MANET encapsulation protocol (IMEP) [6] is a mechanism to aggregate and encapsulate control messages. Also, IMEP provides a generic multi-purpose layer contain-ing various common functionalities for MANET routing pro-tocols. However, in the IMEP speci cation no consideration for signal strength was presented. It may be possible to use IMEP for ltering neighbors based on link stability rather than just to list neighbors that are in range.

Given the observations obtained from our experiments, one possible area of work is to extend upon IMEP's function-alities to incorporate mechanisms to shield wireless defects, and also o er various routing metrics which could be used by routing protocols and one

8. CONCLUSION

In this paper we have outlined our implementation and de-ployment experiences with MAD-HOC's AODV and DSDV. Our experiments have provided insights into the real world deployment of MANETs and highlight issues that require further investigation. These are:

1. **Handling unreliable/Unstable links**.
2. **Minimizing the dependacy on topology speci c param-eters**.
3. **Mechanisms for hando and reducing packet loss dur-ing hando .**
4. **Incorporating neighbor discovery and ltering into a neighbor selection sub-layer**.

The rst issue is a result of the current prevailing MANET protocol development/testing environments which appear to consist almost entirely of simulation experiments using **ns-2** and Glomosim. In implementing two MANET routing protocols, rather than simulating them, we discovered that the variability of networking conditions in the radio envi-ronment was such that the routing protocols did not work as reported in the literature. This led to the development of **powerwave**, and it was found that neighbor selection is crucial in the operation of MANET routing protocols. We believe our observations pertaining to unreliable/unstable links are not restricted to MAD-HOC's AODV implemen-tation given that current AODV speci cation relies on hop

count and does not take into account the reliability of a given route or link.

If The second issue is speci c to a given routing protocol. As argued, having pre-con gured parameters for a given topol-ogy is inappropriate given the inherent dynamic nature of MANETs, and a ects the operation of routing protocols. Therefore, methods for adaptive adjustment of these pa-rameters are required.

On the third issue, current MANET routing protocols do not appear to consider pre-emptive route construction based on signal strength in a similar way to how hando s are done in cellular networks. We have observed that knowing whether a node is going upstream or downstream has added bene-t. The concept of hando , from one route that has a high probability of near term breakage to another route which is more stable is a possible area for future research.

Finally, there is scope for the development of a neighbor selection sub-layer like IMEP that incorporates a range of metrics that could be used by routing protocols. Various lters and heuristics could be developed which will be ben-e cial to MANET routing protocols.

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