A Survey on Traditional and Hybrid Approaches to Broadcasting in MANET

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Abstract

The MANET is a special type of wireless mobile network in which mobile hosts can communicate without any aid of established infrastructure. Broadcast or flooding is a dissemination technique of paramount importance in mobile ad-hoc networks. MANETs are generating lots of interest due to their dynamic topology and decentralized administration. Due to the mobility of nodes there are many problem occurred during the packet transmission. Basic routing protocols such as Ad hoc on Demand Distance Vector (AODV), Dynamic source routing (DSR) could lead to issues such as Broadcast Storm Problem, Large power consumption, link failure due to mobility. This paper concentrates on routing schemes which is the most challenging issue due to the dynamic topology of ad hoc networks. This paper provides an overview of traditional routing schemes and hybrid routing schemes proposed as extensions to basic routing algorithms to enhance their performance. In addition to reviewing the main features of the broadcast schemes found in the literature, we also present an exhaustive review of the evaluation methodology including their performance metrics.

1. INTRODUCTION

Wireless networks are becoming more and more important. People want their mobile and fixed devices to communicate with hassle of wires. Preferably communication should be established automatically in ad-hoc fashion. To achieve this, Mobile Ad-hoc Networks will be an important building block. The MANET is a special type of wireless mobile network in which mobile hosts can communicate without any aid of established infrastructure. If a source node is unable to send a message directly to its destination node due to limited transmission range, the source node uses intermediate nodes to forward the message towards the destination node.

Broadcasting is a widely used dissemination technique in which nodes send out the same information simultaneously to all their neighbors. Broadcasting is used in ad-hoc networks such as Wireless Sensor Networks (WSNs) [4], Mobile Ad Hoc Networks (MANETs) [8], and Vehicular Ad Hoc Networks (VANETs) [13]. In routing protocols for ad-hoc networks, broadcasting is part of the discovery phase, which is responsible for finding a communication path to route the application data from a source node to one or more destination nodes. In MANET, the mobility of hosts enhances link breakage probability. This makes routing protocols meant for wired networks to work inefficiently in MANET.

Many routing protocols in MANET have been proposed. They can be categorized into the two broad classes: proactive/table driven and reactive/on-demand based on the way the route information is maintained and stored. In the proactive routing protocol, every node keeps up-to-date information about all nodes in the network. Each node has a complete view of the network topology. The main advantage of proactive routing is the shortest response time to determine a route. However, it wastes the network resources by using control packets and some routes are not used at all. Destination-sequenced distance vector routing (DSDV) [1] is an example of this type. In reactive routing, routes are created only when a node needs to send data to another node in the network (i.e. on demand). There are no predefined routes. The main advantage is the reduced
overhead on the network because there is no need to exchange information about the network topology. On the other hand, it increases the time needed to calculate a route. Moreover, the source must reinitiate a new route request when the old has failed. Ad hoc on demand distance vector (AODV) [2] and Dynamic source routing (DSR) [11] are examples of reactive protocols.

The simplest way of broadcasting is flooding where each node receives and then transmits the message to all its neighbors. This process continues until the packet has been rebroadcasted throughout the entire network. The main benefit of using flooding is the ease of implementation. But it suffers from redundancy, collision and contention in the network, such a scenario is referred to as Broadcast Storm Problem [3]. In order to alleviate the broadcast storm problem many broadcast sophisticated solution have been proposed in the last decade.

2. TRADITIONAL APPROACHES TO BROADCASTING IN MANET

A basic classification of broadcast schemes divides them into two categories, heuristic based schemes and topology based schemes [5]. In heuristic based schemes, a decision of retransmission is made based on probability, counter, location and distance. In topology based schemes, a decision of retransmission is made based on topological information such as neighboring nodes, number of nodes in the network, type of network (dense network or sparse network).

2.1. Probabilistic Broadcast scheme

The probabilistic broadcast schemes have been proposed to alleviate the broadcast storm problem associated with blind flooding. It inhibits some nodes from forwarding the broadcast packet for the sake of reducing redundancy. It basically allows a node to rebroadcast the message with a certain value of probability \( p \) and eliminate it with \( 1-p \). The selection of the value of \( p \) is decisive and some works have been made so far to find an appropriate measurement to adjust it according to different conditions. Below is a some of suggested methods to select the \( p \) value by different research people. A brief outline of the Probabilistic broadcast scheme in shown in Figure 1.

![Figure 1: Description of Probabilistic Broadcast scheme.](image)

The operation of Probabilistic broadcast scheme is as follows:

- When a packet is arrived for the first time a random number (RN) is generated over \([0,1]\).
- If RN is less than or equal to the fixed probability \( p \) then the packet is broadcasted. Otherwise the packet is dropped.

**Fixed-Probabilistic Broadcast Scheme**

In Fixed Probabilistic Broadcasting all nodes receive a broadcast message for the first time, rebroadcasts it to all other nodes in the network with a certain value of probability \( p \), apart from the density level of current node. A smaller value of \( p \) will reduce the storm effect. The disadvantage of Fixed Probabilistic Scheme is that in sparse network, there is much less shared coverage; therefore some nodes won’t receive broadcast...
packets unless the probability value is high. Y-C. Tseng and J-P Heu [3] have shown that the best value of $p$ in terms of high reach ability and rebroadcast reduced approximately equal to 0.07%.

### 2.2. Counter Based Broadcast Scheme

The counter based broadcast schemes have been proposed to alleviate the broadcast storm problem associated with blind flooding. It inhibits some nodes from forwarding the broadcast packet for the sake of reducing redundancy. The theme behind counter based broadcast scheme is that the broadcast packet may be blocked by busy medium and other queued messages. So there is a chance for the node to hear the same packet again and again from other broadcasting nodes before the node actually start transmitting the packet. This is made possible by inserting a small random delay before broadcasting the packet which causes the timing of the broadcasting be differentiated. This not only allows node sufficient time to receive redundant packets but also prevents collision. A brief outline of the counter based broadcast scheme in shown in Figure 2.

![Protocol receiving](image)

**Figure 2: Description of Counter Based Broadcast scheme.**

The operation of counter based broadcast scheme is as follows:

- When a node receives a packet, it initializes a counter $c$ and will wait for random assessment delay (RAD). The length of RAD is randomly chosen from uniform distribution between 0 to $T_{max}$ seconds, $T_{max}$ is maximum delay time.
- During RAD the counter is counting the number of packets.
- When RAD expires, the counter $c$ is compared to Threshold. If counter $c$ does not reach to Threshold, the packet is broadcasted. Otherwise the packet is dropped.

#### Fixed-Counter based Broadcast Scheme

S. Y. Ni has concluded in [3] that a threshold value 3 or 4 can save many broadcasts. In Fixed Counter based Broadcasting, a smaller threshold will reduce the storm effect. The disadvantage of fixed counter based scheme is that in sparse network, there is much less shared coverage; therefore some nodes won’t receive broadcast packets unless the threshold value is low. In the dense network, keeping low threshold causes redundant broadcast. There exists a trade-off between broadcast savings & reach ability.

### 2.3. Area Based Broadcast Schemes

Research on Area Based Broadcast schemes in mobile ad-hoc networks has proceeded along two main schemes:

- A. Distance Based Schemes
- B. Position Based Schemes
2.3.1. Distance Based Broadcast Schemes

In distance based schemes, the relative distance between the source and destination node is used to make the broadcasting decision. The Euclidean distance is the most used type of distance; however, the Received Signal Strength (RSS) and hop count are also employed. The basic idea is that nodes located further away from the senders are preferred since they avoid redundant retransmissions.

In Euclidean distance-based schemes, nodes have to be equipped with a positioning system like a GPS in order to obtain the Euclidean distance between two nodes [9]. In RSS-based schemes, nodes calculate the relative distance as a function of signal power [9]. Alternatively, as the number of hops is the common metric used by routing protocols to measure the distance between the source node and the destination node [19], this can also be used by the probabilistic broadcast schemes to determine the distance between two nodes. A brief outline of the distance based broadcast scheme is shown in Figure 3.

![Figure 3: Description of Distance Based Broadcast scheme.](image)

The operation of distance based broadcast scheme is as follows:
- When a node receives a packet, it computes its distance from source node $d$
- Wait for random assessment delay (RAD). The length of RAD is randomly chosen from uniform distribution between 0 to Tmax seconds, Tmax is maximum delay time
- When RAD expires, the distance between the source and receiver $d$ is compared with the threshold distance D. If the distance between the source and receiver $d$ exceeds a certain Distance Threshold D, the packet is broadcasted. Otherwise the packet is dropped.

2.3.2. Position Based Broadcast Schemes

According to position based schemes, each node must have the means to establish its own position in order to estimate the additional coverage more precisely. This scheme can be supported by the global positioning system (GPS) [3]. A brief outline of the position based broadcast scheme is shown in Figure 4.

![Figure 4: Description of Position Based Broadcast scheme.](image)
The operation of position based broadcast scheme is as follows:

- When a node receives a packet, it calculates the Expected Additional Coverage (EAC) that the node can cover.
- Wait for random assessment delay (RAD). The length of RAD is randomly chosen from uniform distribution between 0 to Tmax seconds, Tmax is maximum delay time.
- When RAD expires, the EAC is compared with predefined EAC Threshold. If the EAC is less than a predefined EAC Threshold, the node will not rebroadcast the packet, as this does not cover a new region. Otherwise, the node rebroadcasts it.

The problem of position based approach is the cost of calculating Additional Expected Coverage Areas, which is calculating many intersections among many circles.

2.4. Topology Based Broadcast Schemes

In topology based broadcast schemes the topological information is used to take broadcast decision. It is categorized into Neighbor Knowledge Based Scheme and Cluster Based Scheme.

2.4.1. Neighbor Knowledge Based Scheme

Neighbor knowledge based schemes make use of neighboring information to make decision of broadcast[6][9]. Most works use the periodic Hello messages to collect topological information.

A) Self Prunning Scheme

Flooding with self Prunning [7] have suggested a simple neighbor knowledge-based scheme, in which each node periodically exchanges the knowledge of its one-hop neighbors which can be collected by using a “HELLO” packet. A brief outline of Self Prunning scheme is shown in Figure 5.

![Figure 5: Description of Self Prunning scheme.](image)

The operation of self prunning scheme is as follows:

- Every node encloses their neighbor’s identifiers in the flooding message header.
- After receiving a flooding packet from a neighbor it compares its own neighbors list and the senders list and if all its neighbors are not covered by the sender then it broadcasts the packet. Otherwise, it drops the packet.

Unfortunately, Flooding with self pruning is also not saving a lot broadcast compared to blind flooding, because only those nodes which are very close to the sender may have all its neighbors covered by the sender.
B) Scalable Broadcasting Scheme

The scheme in [7] improves the self-pruning scheme as each node includes the knowledge of its neighbors within a two-hop radius instead of a one-hop radius. Also it introduces RAD before broadcasting to differentiate timing of broadcast. The “HELLO” packet technique is used to collect neighborhood information between nodes. Then the node decides whether it can cover new nodes by rebroadcasting the broadcast packet or not. A brief outline of the Scalable Broadcast Algorithm is shown in Figure 6.

![Figure 6: Description of Scalable Broadcasting Algorithm](image)

The operation of Scalable Broadcasting Algorithm is as follows:

- Every node encloses their two hop neighbor’s identifiers in the flooding message header.
- After receiving a flooding packet from a neighbor it compares its own neighbors list and the senders list and if all its neighbors are not covered by the sender then it broadcasts the packet after a random assessment delay (RAD).
- During this period, if duplicate packets received covering all neighbors of the node, the packet is dropped.

2.5. Cluster Based Schemes

In a cluster-based scheme [3] [6], the network is partitioned into several groups of clusters. Each group has a Cluster Head (CH) with gateways nodes responsible of rebroadcasting the message and select forwarding nodes on behalf of the cluster. Each host has a unique ID; a host with a local minimal ID will select itself as a cluster head. If a node receives a message from a neighbor that announced itself as CH, it will send a message (to all its neighbors) declaring itself a non-CH node, to enable more clusters to be created (note that two CHs are not direct neighbors in the algorithm). Thus each node broadcasts its clustering decision after its neighbors with a lower ID have already done so. Non-CH nodes that hear two or more CHs will declare themselves as gateway nodes. A brief outline of the Cluster Based Scheme is shown in figure 7.

![Figure 7: Description of Cluster Based Scheme](image)
The operation of Cluster Based Scheme is as follows:

- When the broadcast packet is heard, if node is Non-CH member, the broadcast is inhibited and the procedure exits.
- When the broadcast packet is heard, if node is CH or a gateway member then it uses any of broadcasting scheme viz. probabilistic, counter based, distance based and position based scheme to take broadcast decision.

In particular Ni et al.[3] showed that the performance of Cluster based using Position based scheme compared favorably to the original position based scheme. The cluster based scheme using Position based scheme saved a lot more broadcasts and lead to shorter average latencies. Cluster based schemes usually demand extensive mathematical computation which drains MANET’s Battery power.

3. HYBRID-BASED APPROACHES TO BROADCASTING IN MANET

The schemes under this classification combine the advantages of two or more different broadcast schemes in order to introduce an optimal broadcasting one to suppress the broadcast storm problem.

3.1. Probabilistic Counter-based Broadcast Scheme (PCBS)[12]

The aim of this research is to suggest efficient probabilistic schemes for MANETs that combine the features of fixed probability and counter-based scheme in order to mitigate the broadcast storm problem deleterious effects without sacrificing reach ability (i.e. the ratio of nodes that can receive a broadcast packet). The broadcast scheme is divided into two phases: the rebroadcast decision phase and the forwarding probability assignment phase. The rebroadcast decision criterion is similar to that of traditional Counter based scheme, where the key rebroadcast decision parameter is the threshold value $C$. However, the forwarding probability assignment phase of the traditional Counter-based scheme has been modified to incorporate the assignment of a fixed forwarding probability value to a node. The rebroadcast decision phase is triggered whenever a node needs to communicate with other nodes in the network or receive a broadcast packet. The source node transmits the broadcast packet to all its 1-hop neighbors. Each neighboring node that receives the broadcast packet initialize a counter and wait for a RAD time during which it increment its counter for every received copy of the same broadcast packet. After the expiration of the RAD time, the node compares its $c$ value against the threshold value. If the $c$ value is less than the threshold value, the scheme proceeds to the second phase where the forwarding probability is assigned. Otherwise, the broadcast packet is dropped and the scheme exit. A brief outline of the Probabilistic Counter-based Broadcast Scheme is shown in figure 8.

**Protocol Receiving()**
- On hearing a broadcast packet $m$ at node $X$ counter$(c)=1$
- Wait for a Random Acess Delay $[0, T_{max}]$
- Increment C
- Loop
  - If $C <$ Threshold
    - Set the forwarding probability to $p$
    - Otherwise, drop it
  - Go to Exit
- Generate a random number $RN$ over $[0,1]$
- If $RN < p$
  - Rebroadcast the received packet
  - Otherwise, Drop it
- Exit

**Figure 8: Description of Probabilistic Counter Based Scheme**
The use of single fixed forwarding probability for all nodes in the network regardless of whether the node is in sparse or dense region of the network has make it inflexible in a typical MANET scenario where regions of varying node density co-exist in the same network.

3.2. Adjusted Probabilistic Counter-based Broadcast Scheme [14]

As network topology in MANETs is highly dynamic due to node mobility which often resulted in frequent changes in the node distribution in this network. Therefore, the forwarding probability used in probabilistic broadcast schemes for the dissemination of broadcast packets should be set dynamically to reflect the local neighborhood information of a given node, i.e., the packet counter value of a given node which determine whether the node is located in a sparse or dense region [10].

The aim of this research is to significantly reduce the broadcast redundancy without sacrificing network reach ability for a given network topology by dynamically adjusting the forwarding probability at a node according to the counter value of the given node.

Adjusted Probabilistic Counter-based Broadcast Scheme partitions the network into two parts (i.e. sparse and dense networks) using the threshold value. The first part encompasses nodes with counter values less than the threshold value and this is the part where broadcast packet forwarding is considered highly desirable. On the other hand, the second part (dense network) consists of nodes with packet counter value greater than the threshold value and in this case where rebroadcast of packet need to be minimized because no much additional coverage can be gained by forwarding the packet. Therefore, both the nodes within the two parts of the network are allowed to forward the broadcast packet with a forwarding probability dynamically determined using the counter value at the forwarding node and the threshold value.

The broadcast decision phase and the forwarding probability assignment phase of Adjusted Probabilistic Counter-based Broadcast Scheme are both triggered in the same manner as in Probabilistic Counter-based Broadcast Scheme. Unlike the Probabilistic Counter-based Broadcast Scheme where each node is assigned a predetermined forwarding probability value, the nodes dynamically compute their forwarding probabilities using a probability function which depends on the packet counter value at a given node (i.e., local density) and the threshold value.

The nodes with few numbers of neighbors should be assigned a high rebroadcast probability while those with high number of neighbors should be assigned a low rebroadcast probability. Therefore, as the number of neighbors increases, the rebroadcast probability should decreases. Based on the above features and specifications identified for the forwarding probability, an ideal mathematical function that can fit into these requirements is the exponential function.

Let \( c \) be the counter value (i.e. number of neighbors) of a given node and let \( C \) be the counter threshold value. The forwarding probability at node is defined as follows:

\[
F(c) = \begin{cases} 
\frac{e^{-c}}{Threshold} & \text{if } c < Threshold \\
\frac{e^{-c+2}}{Threshold} & \text{otherwise}
\end{cases}
\]

Equation 1

A brief outline of the Adjusted Probabilistic Counter-based Broadcast Scheme is shown in figure 9.
3.3. New Probabilistic Based Broadcasting Algorithm for Mobile Ad Hoc Networks [10]

The topology of MANET is often random and dynamic with varying degree of node density in various regions of the network. The network may contain sparse and dense regions. It should be noticed that in sparse networks there is much less shared coverage; thus some nodes will not receive all the broadcast packets unless the probability parameter is high. So if the rebroadcast probability \( p \) is set to a far small value, the reach ability will be poor. On the other hand, if \( p \) is set far large, many redundant rebroadcasts will be generated. In order to achieve both high saved rebroadcast and high reach ability in MANETs where network topology changes frequently, the rebroadcast probability at every host must be dynamically adjusted.

The objective of New Probabilistic-Based Broadcasting Algorithm for Mobile Ad Hoc networks is to achieve broadcast savings and high reach ability by dynamically adjusting the rebroadcast probability according to the neighborhood information. The algorithm compares the number of neighbors of node with the average number of nodes in the network to characterize nodes neighborhood. It is the combination of Probabilistic and Neighbor Knowledge Based schemes.

On hearing a broadcast message \( m \) at node \( X \), the node rebroadcast a message according to a high probability if the message is received for the first time, and the number of neighbors of node \( X \) is less than average number of neighbors typical of its surrounding environment. Hence, if node \( X \) has a low degree (in terms of the number of neighbors), retransmission should be likely. Otherwise, if \( X \) has a high degree its rebroadcast probability is set low.

A brief outline of the A new Probabilistic Based Broadcast Scheme is shown in figure 10.
3.4. New Counter Based Broadcasting Algorithm for Mobile Ad Hoc Networks

The aim of this research is to suggest an algorithm that achieves broadcast savings and high reach ability in order to mitigate the broadcast storm problem by combining the features of counter-based scheme and Neighbor Knowledge Based scheme.

Ideally, the threshold value $c$ should be high in a node located in a dense region while relatively low in a node located in sparse region. If is too high reach ability might be poor while if $c$ is set too low, many redundant broadcast may be generated. While using small threshold values provides significant broadcast savings, unfortunately the reach ability will be poor. There exist a tradeoff between reach ability and broadcast saving. In order to achieve both high broadcast savings and reach ability, the threshold should be set low for the nodes located in sparse regions and high for the nodes located in dense regions. A high number of neighbors implies that the nodes in dense region and a low number of neighbors imply that the nodes in the sparse region.

On hearing a broadcast message $m$ at node $X$, it does not immediately broadcast the packet. It waits for Random Assessment Delay (RAD). If the number of neighbors of node $X$ is less than average number of neighbors then the value of Counter threshold ($c1$) is set to low value. If the number of neighbors of node $X$ is more than average number of neighbors then the value of Counter threshold ($c2$) is set to high value. During RAD, the counter is counting the number of repeated packets received. When RAD expires, if counter $c$ is less than threshold, packet is broadcasted; Otherwise packet is dropped.

A brief outline of the A new Counter Based Broadcast Scheme is shown in figure 11.

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**Figure 10: Description of A new Probabilistic Based Broadcasting Scheme**

![Protocol Receiving()](image)
3.5. A New Adaptive Broadcasting Scheme [15]

The main finding of A New Adaptive Broadcasting Approach is to find an effective solution on Broadcast Storm Problem by adjusting the forwarding probability $P$ based on the global and local neighborhood information and thus reducing dependency on using thresholds to determine the degree level of density for a given node.

When a node $x$ receives a RREQ packet for the first time, it first calculates the number of neighbors $N$-Hello by broadcasting HELLO packets for 1-hop to collect local information about the surrounding neighbors. Similarly, the node $x$ calculates the number of neighbors $N$-Transmission within its transmission range to collect global information about the surrounding node environment. Our experiments show that collecting neighborhood information by using 1-hop HELLO packet does not give a complete view to decide whether the current node is located in dense or sparse area compared by $N$-Transmission which provides general and more precise information about nodes’ density. For example, when a number of nodes in the network are equal 100 and the transmission range is 250 m, the average values of the neighbors with $N$-Transmission = 55 and N-Hello = 25. This means that the node is considered located in a sparse area according to N-Hello value while it is actually located in a dense area according to N-Transmission value. A brief outline of the A new Adaptive Broadcasting Scheme is shown in figure 12.

![Figure 11: Description of A new Counter Based Broadcasting Scheme](image)

**Protocol Receiving()**

- On hearing a broadcast packet $m$ at node $X$
- Get the Broadcast ID from the message;
- Calculate $\bar{n}$ Average number of neighbors (Threshold value);
- Get degree $n$ of a node $X$ (number of neighbors of node $X$)
- If Packet $m$ is received for the first time then
  - If $n < \bar{n}$ then
    - Sparse region: Low Threshold
      - Threshold = $c_1$
  - Else $n \geq \bar{n}$
    - Dense region: High Threshold
      - Threshold = $c_2$
  - End If

- End If

- Wait for Random Assessment Delay
- Increment $c$
- Loop
  - If $c \leq$ Threshold
    - Rebroadcast the received packet
  - Otherwise,
    - Drop it
  - Exit
3.6. Mobility aware Velocity Based Broadcasting Scheme [16]

Many of routing protocols operate efficiently under low network mobility conditions and do not adapt well with high mobility conditions. Therefore, considering mobility is a demanding task that should be performed efficiently and accurately. The aim of Mobility aware Velocity based Broadcasting Scheme is to eliminate many redundant broadcasts by choosing the nodes with low mobility to discover a more stable path. Thus avoiding the frequent link breakages associated with using unstable paths that contain high mobile nodes.

It divides the nodes into high speed nodes and low speed nodes. High Speed nodes do not participate in the route discovery phase, since they produce unstable routes. Unstable routes leads to more broadcasts that will increase the overhead and the delay time to reach the destination.

In Mobility aware Velocity based Broadcasting Scheme, when the intermediate node i receives the packet & it is not the destination, it compares its velocity (Vi) with the fixed velocity threshold (Vth) if Vi <= Vth then the node will rebroadcast the packet to its neighbors, else it will discard the packet. Vth is computed using the equation (2)

\[ V_{th} = P \times \text{Max} \ V \]  

where P is the ratio of the number of slow nodes to the number of all nodes,

Max V is the maximum velocity

A brief outline of the Mobility aware Velocity based Broadcasting Scheme is shown in figure 13.
3.7. Hybrid Broadcasting Scheme [18]

Hybrid Broadcasting Scheme aims to reduce the overheads in mobile networks using an adaptive probabilistic flooding scheme based on neighbor knowledge and a forwarding zone criterion. The term ‘expansion metric’ (defined below), which differentiates the density of nodes in different areas of the deployed scenario is defined to measure the neighborhood information. In addition, a forwarding zone criterion has been defined to control the forwarding probability. The forwarding zone criterion has two major objectives, i.e. to reduce the control messages due to broken links, and to detect the dissimilarity among the forwarding nodes and select the most dissimilar nodes. The forwarding zone is implemented using a nodes positioning information. This information can be obtained from a Global Positioning System(GPS) or using Received Signal Strength(RSS). The Hybrid Broadcasting Scheme eliminates the need for the nodes to cache a node’s ID. They only count the number of 1-hop and 2-hops neighbors in order to calculate the expansion metric, and the request packets contain only the expansion metric.

Expansion metric (E) is a density metric which determines how dense the 2 hops neighborhood of a node is. It is calculated using equation 3.

\[ E = \frac{d2h}{d} \]  \hspace{2cm} \text{Equation 3}

where \( d2h \) is the number of 1-hop neighbors, \\
\( d \) is the number of 2-hop neighbors.

The difference between the two values of E in a broadcast path could be considered as the metric that indicates whether the value of P should be increased or reduced along the broadcast path. In this letter the value of P is adjusted hop by hop depending on the value of E as shown below. The forwarding probability \( P(Et,Et−1) \) can be expressed as:

\[
P(Et,Et−1) = \begin{cases} 
    Pi + Pd(Et,Et−1) & Et < Et−1 \\
    Pi - Pd(Et,Et−1) & Et > Et−1 \\
    Pi & Et = Et−1 
\end{cases}
\]  \hspace{2cm} \text{Equation 4}

Where \( Pd(Et,Et−1) \) is the density dependent probability and \( Pi \) is the initial value of the probability for forwarding an incoming packet. \( Pi \) ensures reach ability and avoids die out Problem. \( Et \) is the expansion metric at the intermediate nodes. Note that the broadcast decision is made based on 3 hops nodes’ information. However, in the above approach, the neighbors located closer to the broadcast node will not explore new areas since their transmission ranges are likely to cover the same area. So, the proposed density dependent approach has been improved by taking the distance among the nodes into account. Larger the distance between two nodes, the higher the dissimilarity between the nodes’ neighbors is. However, mobile bordering nodes are likely to get out of the node’s transmission area [17], and thus will cause broken links. Whenever a broken link occurs a new discovery phase should be started which in turn will increase the use of control messages. Therefore, an improved forwarding zone is proposed in this letter to improve the connectivity. The general principle of the proposed scheme is shown in Fig. 2. The x-axis represents the Euclidean distance \( d \) between two nodes I and J, I being the source node, and J a possible intermediate node located in the forwarding zone. The y-axis represents the forwarding probability \( P \). This forwarding zone has two boundaries namely, \( rb \) and \( re \). While \( re \) determines the dissimilarity between the two nodes, \( rb \) avoids including bordering nodes in new routes. With \( re \) a new area of exploration \( re = \pi((r+re)^2−r^2) m^2 \) is guaranteed at each hop. Whereas, the value of \( re \) guarantees a minimum link’s lifetime = \((r−rb)/Vmax\), where, \( Vmax \) is the node’s maximum speed. If the intermediate node is located outside the forwarding zone, the probability of forwarding the incoming packet is zero, see Fig. 14. Otherwise, the value of P is calculated using equation (4)
4. PERFORMANCE METRICS

The objective of this subsection is to present a detailed list of metrics widely used for the evaluation of broadcast schemes. The broadcast efficiency metrics evaluate the broadcast schemes as a stand-alone dissemination technique. We have classified the broadcast efficiency metrics into three categories viz. Reachability, Redundancy and delay. The reachability metrics measure the outreach of the broadcast process. The redundancy metrics determine the overhead caused by the broadcast schemes. In general, low redundancy is a basic requirement for broadcast schemes. Delay metrics calculate the time elapsed during the broadcast process. Delay needs to be small when broadcast schemes are used to disseminate warning messages.

4.1. Reachability

The objective of this metrics consists of evaluating the dissemination of the broadcast message throughout the network, so high values of the following metrics are always desired in a broadcast scheme.

- Reachability (Re): is defined as the ratio of nodes that received the broadcast packets to the total number of nodes in the network. When the network is not fully connected, the reachability metric is defined as the ratio of nodes that received the broadcast packets to the total number of nodes that can be reached by the source node directly or through a multi-hop path. This metric is also referred to as the fraction of nodes, Broadcast Delivery Ratio (BDR).
- Average Reachability per broadcasting (Reavg): Average reach ability of the broadcast processes executed.

4.2. Redundancy

The following metrics evaluate broadcast schemes in terms of redundancy. In general, redundancy should be maintained as low as possible in broadcast schemes. The ideal scenario is one where nodes only receive a broadcast packet once.

- Saved Re Broadcast (SRB): Let Nr be the number of nodes that received the broadcast message and let Nt be the number of nodes that actually transmitted the message. The saved rebroadcast is then defined by \( \frac{N_r - N_t}{N_r} \).
- Redundancy Overhead (RO): The number of duplicated packets received at each node divided by the total number of nodes in the network.
- Number of forwarding nodes (FN): The number of duplicated packets received at each node divided by the total number of nodes in the network.
Number of retransmissions (NR): The total number of retransmissions. This metric is also referred to as number of rebroadcasts.

Average retransmissions per broadcasting (NRavg): The average number of retransmissions per broadcasting. It is very similar to the previous term, but it also considers the number of broadcast process.

Average Forwarding Percentage (AFP): Forwarding percentage of a given node with respect to the source node, is the percentage of messages originated at the source node and forwarded by the node. The AFP is the reception percentage, averaged over all nodes.

4.3. Delay

Delay metrics are related to the time spent by a broadcast message to cross the network. As a rule, low delay is always a good feature of a broadcast scheme especially when the broadcast scheme is used to disseminate emergency messages.

Flooding Completion Time or Broadcast end to end delay: The time elapsed between the first broadcast of a broadcast packet and the received route reply.

5. SUMMARY

By exploiting the wireless network technology’s advantages over the wired network, many researchers are engaged to develop better solution for the different wireless networking aspects. Routing is an important operation that has attracted researchers to enhance the performance of Wireless networking solutions. In this survey, we first discussed on the blind flooding which causes broadcast storm problem. Alternatively, we discussed on the variety of traditional routing schemes to alleviate broadcast storm problem. These schemes proposed in the literature focusing on their functionalities, strengths & shortcomings are reviewed. In addition, we have surveyed the schemes which combine the advantages of two or more different traditional broadcast schemes in order to introduce an optimal broadcasting scheme to suppress the broadcast storm problem. While reviewing the main features of the broadcast schemes found in the literature, we also presented an exhaustive review of the evaluation methodology.

References