Exploiting Wireless Networks, through creation of Opportunity Network – Wireless-Mobile-Adhoc-Network (W-MAN) Scheme

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ABSTRACT

Spotting Opportunity today and recognizing the same is the vision of the expert. The wireless communication network regime is one such environment that offers such a platform for many working scientific, academic and engineering experts. Henceforth, "Opportunistic-network" is a recent evolution of the above said phenomena in the wireless community. They function by spontaneous cooperation & coordination giving birth to a special type network called ***wireless-mobile-adhoc-network*** *(W-MAN). As said, these networks are formed instantaneously in a random manner – breaking the conventional mathematically evolved algorithms', and provided the quintessential of a network(s) that exist in neighbourhood(s) or approachable limits. Is more of situational based, exploited for specialized purpose or advantage, which mimics all the characteristic of a well evolved network. Such networks, lack an end-to-end path, contact, cooperation and coordination; which is mainly opportunity based, and break or even disintegrate soon after discovery, thus the challenge lay in integration, construction and probable sustenance or even mid-way reconstruction till purpose. One can cite many realistic scenarios fitting to this situation. For example, wildlife tracking sensor networks, military networks, vehicular ad hoc networks to mention a few. To transmit information under such circumstances/scenarios researchers have proposed various efficient forwarding (single copy), replication routing and controlled based schemes. In this paper, we propose to explore, investigate and analyze most of the schemes [1] [2] [3] [4] [5] [6] and present the findings of the said scheme by consolidating critical parameters and issues and towards the end of this paper, algorithms, possible solutions to deal with such complex and dynamic situations through W-MAN scheme suggested by us.*

KEYWORDS

Adhoc networks, opportunistic networks, W-MAN, intermittent connectivity, routing, algorithms, performance

1. INTRODUCTION

W-MAN is a network where the nodes are so sparse or moving in such a way that there exist at least two groups of nodes for which there is no contemporaneous path between the nodes. If the node movement is such that the inter contact times are unknown and unpredictable then the node contacts are called opportunistic. The enabler to route in opportunistic networks or delay tolerant networks (DTN) [7] is node mobility. Over time, different links come up and down due to node mobility. If the sequence of connectivity graphs over a time interval is overlapped, then an end-to-end path might exist. This implies that a message could be sent over an existing link, get buffered at the next hop until the next link in the path comes up (e.g., a new node moves in range or an existing one wakes-up), and so on and so forth, until it reaches its destination. This model of routing constitutes a significant departure from existing routing practices. It is usually referred to as "mobility-assisted" routing; because node mobility often needs to be exploited to

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deliver a message to its destination (other names include "encounter-based forwarding" or "store-carry-and-forward"). Routing here consists of independent, local forwarding decisions, based on current connectivity information and predictions of future connectivity information, and made in an opportunistic fashion.

Despite a number of existing proposals for opportunistic routing [8] [9] [10] [11], the answer to the previous question has usually been "one" or "all". The majority of existing protocols are flooding-based that distribute duplicate copies to all nodes in the network [8] or forwarding based that forwards single copy in the network [12] [13]. Although flooding can be quite fast in some scenarios, the overhead involved in terms of bandwidth, buffer space, and energy dissipation is often prohibitive for small wireless devices (e.g., sensors). Other end, single-copy schemes that only route one copy per message can considerably reduce resource wastage [12] [14]. Yet, they can often be orders of magnitude slower than multi-copy algorithms and are inherently less reliable. These latter characteristics might make single-copy schemes very undesirable for some applications (e.g., in disaster recovery networks or tactical networks beyond enemy lines; even if communication must be intermittent, minimizing delay or message loss is a priority). Summarizing, no routing scheme for extreme environments currently exists that can achieve both small delays and prudent usage of the network and node resources.

For this reason, researchers have proposed controlled copy schemes [1] [15], also known as controlled replication, which can achieve both low delays and good transmissions. We have study, analyze and investigate the various controlled based replication schemes. Our objective is to present the detailed survey on these techniques, parameters and explore the problem space for future extension.

2. RELATED WORK

Although a large number of routing protocols for wireless ad hoc networks have been proposed [16] [17] traditional routing protocols are not appropriate for networks that are sparse and disconnected. The performance of such protocols would be poor even if the network was only "slightly" disconnected. Due to the uncertainty and time-varying nature of DTNs, routing poses unique challenges. As mentioned in literature [18], some routing approaches are broadly based on forwarding approaches [10] [12] [19] [20] [21].Forwarding scheme(s) uses single message copy and thus, optimizes usage of network resources but suffers from higher delivery delay and poor message transmission ratio; Others are based on flooding or multi copy spreading approach [2] [8]. This scheme achieves better delivery ratio but, in turn, suffers from poor resource utilization and contention. Thus, researchers have proposed controlled based replication schemes [1] [2] [3] [4] [5] [6] [15] as solution to achieve better delivery ratio and optimal resource utilization. We present evolution of various controlled based replication approaches and investigate problem space as how to achieve efficient performance or improve existing scheme with limited number of message copies.

3. Routing Classification

Routing in opportunistic networks is broadly classify based on number of copies distributed into network namely single copy (forwarding), Multi copy (replication / flooding) and fixed number of copies (controlled replication / quota based replication/ hybrid scheme.) Table-1[24] briefs about important characteristics of each of this scheme with important parameters.

Table-1 Comparative of message copy techniques

Parameters	**Single copy**	**Multiple Copy**	**Controlled Copy**
Reference protocol cited for comparative	Direct delivery [11] [19]	Epidemic[8]	Binary Spray and Wait [15]
Message copies	Single	Many	Fix number
No. of transmission	Lower	Many	Lower than multiple copy
Delivery delays	Higher	Lower	Lower than single copy
Delivery ratio	Lower	Higher	Better than single copy
Contention	No	Higher	Lower
Network resource wastage	No	Higher	Lower than multi copy
Network resource wastage	No	Higher	Lower than multi copy

4. CONTROLLED COPY/REPLICATION SCHEMES

Thrasyvoulos Spyropoulos et.al. has described controlled replication as "When a new message is generated at a source node, this node also creates L "forwarding tokens" for this message. A forwarding token implies that the node that owns it can spawn and forward an additional copy of the given message". During the spraying phase, messages get forwarded according to the following rules:

- if a node (either the source or a relay), carrying a message copy and $c > 1$ forwarding tokens for this message, encounters a node with no copy of the message1, it spawns and forwards a copy of that message to the second node; it also hands over $l(c)$ tokens to that node ($l(c)$ $[1; c\text{-}1]$) and keeps the rest c ¡ $l(c)$ for itself ("Spray" phase);

- When a node has a message copy and $c = 1$ forwarding tokens for this message, then it can only forward this message to the destination itself ("Wait" phase).

let's look at various controlled replication schemes from its evolution to trends (latest) comprising broadly an input, output, assumptions, algorithm, spraying schemes, message and node distribution, mobility model used, advantages and disadvantages.

4.1. Source Spray and Wait (SNW)

Input: Area, Transmission Range, No. of nodes, Message copies, Mobility model, TTL

Output: Average delivery delay, No. of message transmission

Assumption: No contention, infinite buffer and bandwidth

Algorithm [2]:

- Set up the network with input parameters & randomly select source and destination nodes
- All the nodes are homogeneous in nature.
- Source node carries initially L copies of message M.
- Source moves and suppose encounters n distinct relays without message copy.

- Then, it forwards one of L copies of Message M to each encountered node. If destination Is found, message is forwarded otherwise source/relay node continues searching Destination for direct transmission.
- Each node /relay carrying the message copy in turn will only allowed to forward to Destination if encountered. Thus it performs direct transmission towards destination.
- All the node moves are IID & according to given mobility model.
- This scheme has highest delivery delay.

Advantage: Fewer transmission than epidemic, low contention under high traffic, scalable, Requires little knowledge about network.

Disadvantage: Only source node is allowed to spray copies. Thus, it incurs considerable Delay & needs to investigate the performance in realistic situation.

4.2. Binary Spray and Wait (BSW)

Input: Area, Transmission Range, No. of nodes, Message copies, Mobility model, TTL

Output: Average delivery delay, No. of message transmission

Assumption: No contention, infinite buffer and bandwidth

Algorithm [2]:

- Set up the network with input parameters & randomly select source and destination nodes.
- All the nodes are homogeneous in nature.
- Source of message starts with L copies; when a node A (Source node or relay node) that has n >1 message copies encounters node B (with no copies) it hands over to B [n/ 2] and keeps [n/2] for itself
- When A has only one copy left , it switches to direct transmission and forwards the message only to its destination
- All the node moves are IID & according to given mobility model.
- It is optimal spraying strategy with lowest delay compared to other scheme.

Advantage: Fewer transmissions than epidemic, low contention under high traffic, scalable, Requires little knowledge about network

Disadvantage: It does blind fold forwarding (random) of message copies. It needs to Investigate the performance in realistic situation.

4.3. Spray and Focus

Input: Area, Transmission Range, No. of nodes, Message copies, Mobility model, TTL, age of encounter timers

Output: Average delivery delay, No. of message transmission

Assumption: No contention, infinite buffer and bandwidth

Algorithm [1]:

- Set up the network with input parameters & randomly select source and destination nodes. All the nodes are heterogeneous in nature.
- Each node maintains a “message vector” with IDs of all messages that it has stored, and for which it acts as a relay.
- Whenever two nodes encounter each other, they exchange their vectors and check which messages they have in common Source of message starts with L copies; when a node A (Source node or relay node) that has n >1 message copies encounters node B (with no copies) it hands over to B [n/ 2] copies and keeps rest [n/2] for itself.
- When node A has only one copy left, it can be forwarded using single copy utility based routing technique.
- Each node *i* maintains a timer $\tau_i(j)$ for every other node *j* in the network, which records the time elapsed since the two nodes last encountered each other as follows: initially set $\tau_i(j) = 0$ and $\tau_i(j) = \infty$, $\forall\, i, j$; whenever *i* encounters *j*, set $\tau_i(j) = \tau_j(i) = 0$;
- At every clock tick increase each timer by 1. Position information regarding different nodes gets indirectly logged in the last encounter timers, and gets diffused through the mobility process of other nodes.
- Therefore, we can define a utility function, based on these timers, that indicates how “useful” a node might be in delivering a message to another node.
- Every node i maintain a utility value U_i (j) for every other node j in the network. Then, a node A forwards to another node B a message destined to a node D, if and only if $U_B(D) > U_A(D) + U_{th}$, where U_{th} (utility threshold) is a parameter of the algorithm.
- When node A sees node B often, and node B sees node C often, A may be a good candidate to deliver a message to C (through B), even if A rarely sees C. Therefore, when A encounters node B, it should also update (increase) its utility for all nodes for which B has a high utility.
- Utility based routing uses timer transitivity. Let a node encounter a node B at distance d_{AB}. Let further $t_m(d)$ denote the expected time it takes a node to move a distance d under a given mobility model. Then: $\forall\, j \neq B : \tau_B(j) < \tau_A(j) - t_m(d_{AB})$, set $\tau_A(j) = \tau_B(j) + t_m(d_{AB})$.

Advantage: Improves the performance by twenty times than spray & wait

Disadvantage: Finding optimal distribution strategy

4.4. Spray and Wait with average delivery probability

Input: Area, Transmission Range, No. of nodes, Message copies, Mobility model, TTL

Output: Average delivery delay, No. of message transmission

Assumption: No contention, infinite buffer and bandwidth

Algorithm [3][10]:

- Set up the network with input parameters & randomly select source and destination nodes. All the nodes are homogeneous in nature.
- In binary spray and wait, when a node A (Source node or relay node) that has n >1 message Copies encounters node B (with no copies) it hands over to B [n/ 2] and keeps [n/2] for itself.

- Rather forwarding in random & blind fold way, it uses average delivery probability using Probabilistic Routing Protocol using a History of Encounters and Transitivity (PROPHET).
- When node A encounters node B for the first time, the delivery predictabilities is calculated: $P_1(a,b) = P_{init}$
- Node A records $P_1(a,b)$ and t_1 which is the interval from network initializing to the time which node An encounters node B for the first time.
- When node A encounters node B the second time, the delivery predictabilities at the second encountered time is calculated by: $\mathbf{P_2(a,b) = P_1(a,b) + (1- P_1(a,b))\times P_{init}}$
- Node A records t2 which is the interval from the first encountered time to the second encountered time And then, the average delivery predictabilities from node A to B at the second encountered time can be calculated by: $\mathbf{P_{avg(2)}(a,b) = (P_1(a,b)\times t_1 + P_2(a,b)\times t_2)/(t_1 + t_2)}$.
- At the n encountered time, the average delivery predictabilities from node A to B can be calculated by:
  $$P_{avg(n)(a,b)} = (P_{avg(n-1)(a,b)} \times \sum_{1}^{n-1} t + P_{n(a,b)} \times t_n) / \sum_{1}^{n} t$$
- if node A which posses n copies of this message encounters node B and $P_{avg}(b,d) > P_{avg}(a,d)$, A will hand over B, n/2 messages and keeps n/2 for itself. If $P_{avg}(b,d) <= P_{avg}(a,d)$, A will not forward messages to B.
- When A has only one copy left , it switches to direct transmission and forwards the message only to its destination

Advantage: Shorter delay with small value of message copy L needs Buffer management policies for history and messages

Disadvantage: History management and synchronization.

4.5. Fuzzy Spray and Wait

Input: Area, Transmission Range, No. of nodes, Message copies, Mobility model, TTL, FTC, Message size

Output: Average delivery delay, No. of message transmission

Assumption: Finite storage and bandwidth, Pragmatic assumption

Algorithm [4]:

- Fuzzy-spray uses fuzzy technique to prioritize messages that are stored in the buffer, and then transfers (so called “spray”) as many messages from the buffer to its peer as possible, during its contact time.
- It uses two parameters, forward transmission count (FTC) and message size which are updated using simple rule.
- Count of duplicated message (CDM) is first metric used to compute message transmission.
- To estimate CDM, hop count is used. Set initial value of Hop count and CDM to 1 at source node. Hop count value is increases by 1 at receiving node.
- FTC value is increased by 1 at sender and receiver node if it is delivered successfully.
- Its value is accumulated and forwarded. Large FTC count ensures most of the node in that route has copy of message in its buffer. It is not necessary to further spread message copies. Hence, message with higher FTC count has lower priority for message transmission.

- FTC with the lower counts means message is not sprayed and should be transmitted with higher priority.
- FTC membership function divided into three section low, medium and high & Message is also divided into small, medium and large.
- Messages are divided into nine buffer section and put with fuzzy rule.
- Defuzzifier process, Centre of Area (*COA*) is applied to create a crisp value. The priority of a message, *P*, is $1 - COA$, and the messages in buffer are all sorted by values of their *P*, from highest to lowest, where highest *P* value is at the head of the queue, and lowest *P* value is at the tail

Advantage: Less sensitive to chosen parameters (fuzzy membership function)

Disadvantage: Needs to investigate the performance in real trace based mobility models with Heterogeneous nodes.

4.6. Oracle based Spray and Wait (O-SW)

Input: Area, Transmission Range, No. of nodes, Roller net trace data set, TTL

Output: Average delivery delay, No. of message transmission

Assumption: Contention free access, Infinite bandwidth, Infinite storage

Algorithm [5]:

- Set up the network with input parameters & randomly select source and destination nodes. All the nodes are heterogeneous in nature.
- Current status of network is known to O-SW.
- Based on this it dynamically determines number of copies to be sprayed in distributed way.
- The oracle is capable of determining the most adequate number of copies adaptive routing strategies which control the dissemination effort with regards to node density

To send depending on some criterion.

Advantage: Sprays most adequate number of copies in adaptive way.

Disadvantage: It is theoretical. Cannot be realized.

4.7. Density aware of spray and wait

Input: Area, Transmission Range, No. of nodes, Roller net trace data set, TTL

Output: Average delivery delay, No. of message transmission

Assumption: Contention free access, Infinite bandwidth, Infinite storage

Algorithm [5]:

- Set up the network with input parameters & randomly select source and destination nodes. All the nodes are heterogeneous in nature.

- Whenever a node has a bundle to transmit, it computes its current connectivity degree and refers to the abacus to determine the exact number of copies that is expected to lead to some expected delay.
- Connectivity degree is the number of neighbours a node has within the latest 30 seconds.
- Abacus consists in the average delay experienced by a number of SW(n) variants as a function of the average node degree observed when packets were generated.
- Thus, the source sends more copies of a bundle when the topology is sparse and fewer copies when the topology becomes denser as per node density.
- Node movement is captured from roller net tour trace data set.

Advantage: Controls communication overhead keeping delay within expected bounds.

Disadvantage: Needs good predictors for anticipating changes in mobility patterns and thus Node degree.

2.8. Dynamic Spray and Wait:

Input: Area, Transmission Range, No. of nodes, Message copies, Mobility model, TTL

Output: Average delivery delay, No. of message transmission

Assumption: Finite buffer

Algorithm [6]:

- Set up the network with input parameters & randomly select source and destination nodes. All the nodes are homogeneous in nature.
- In binary spray and wait, when a node A (Source node or relay node) that has n >1 message Copies encounters node B (with no copies) it hands over to B, [n/ 2] and keeps [n/2] for itself.
- Rather forwarding in random & blind fold way, it uses ratio of QoN (Quality of node) for forwarding the message copies.
- QoN indicates the activity of a node, or the number one node meets other different nodes within a given interval.
- In opportunistic network node dynamically join or leave. Longer the stay of node in network higher will be QoN and for shorter stay it will be low.
- QoN is computed for each fragment and influence is measured of former fragment on current fragment. Time fragments are divided into h.

$$\sum_{i=1}^{h} t_i = T, \qquad t_1 = t_2 = \cdots = t_h$$

- Using Jacobson formula [22], QoN for each node can be updated by equation :

$$Q = \alpha \cdot Q_{old} + (1-\alpha) \cdot Avg_k$$

$$Avg_k = \frac{k_2 - k_1}{\Delta t} \cdot T$$

- α is smoothing factor and determines degree of influence.
- Avg_k is the number of other nodes that one node experiences in the network during the period of time from the end time of former fragment to the current time. Nodes must first update Avg_k and Q at each connection.

- Update process can be describe using following pseudo code

```
k = 0; kold = 0;
Q = 0; Qold = 0;
last_update_time = 0;
α = 0.15;
if (connection is on) {
++ k;
DTNHost.updateQ( ); }
updateQ ( ) {
Avgk = (currect_k - kold)*3600 / (current_time
        last_update_time);
if (last_update_time = = 0)
Q = Avgk;
else
Q = α * Qold + (1 - α) *Avgk;
timeDiff = (current_time - last_update_time);
if (timeDiff >= 3600) {
kold = this time_k; Qold = this time_Q;
last_update_time = this _time; } }
```

- When two nodes encounter, they will update the QoN at first and exchange QoN with each other, and then forward message copies according to the ratio of QoNs The source of a message initially starts with L copies and then message copies are forwarded from A to B is $N2 = Q2 / Q1 + Q2 * N1$
- Node A keeps $N1' = N1 - N2 = (1 – Q2 / Q1 + Q2)*N1$ copies for itself.

Advantages: Adapts to real dynamic network conditions, enhances delivery utility

Disadvantages: Needs to make more energy efficient

4.9. Utility based spraying schemes:

In heterogeneous node environment to find best relay for forwarding the message node's utility is used as heuristic. Based on these following spraying schemes have been evolved:

4.9.1. Last-seen-first (LSF) spraying

- Choose as relays the nodes that have seen the destination most recently
- Each node keeps encounter timers which keeps the records of two nodes last encounter with each other.
- Reason behind keeping age of encounter timer is to advance single copy towards its destination using gradient based routing.
- This scheme best fits for the scenario when nodes are divided into group and members in group more often see each other than outside the group.

4.9.2. Most-mobile-first (MMF) spraying

- This scheme assumes some nodes are more mobile than others. (In general more capable).
- Each node carries some label (e.g. TAXI, BUS, CAR ...) which classifies the node type.
- Then labels are but in preference order : e.g. LABEL1 > LABEL2 > LABLE3

- One could have different preference order depending upon the type of node.

4.9.3. Most-Social-First (MSF) spraying

- Some nodes might encounter other more than average not just due to mobility but may visit Some location more often than other or have more social links than average. Hence, this Scheme focuses on sociability than mobility.
- Sociability value of a node will be a function of the time interval during which it is measured. If a node's statistical behaviour varies over time, then its sociability index might also change Between time intervals.
- This implies that it might be more appropriate for a node maintain a running average of its perceived sociability index, rather than just looking at the previous interval.
- Each node I maintains its running index of sociability (Si)for given interval t_n = ((n-1) T, nT) called sliding window. It counts uniq encounters during this interval $N_i(n)$. Then at the end of sliding window, social index Si is updates as Si = $(1 - \alpha)$ Si + α $N_i(n)$ / T and proceeds to the next interval t_{n+1}, where α is weighting factor given to sliding window.
- Finally utility of node i is given by Ui(j) = Ui = Si

3. CONCLUSIONS & FUTURE WORK

We have presented through investigation followed by an analysis along with summary regarding controlled based replication schemes with an objective that it turns out be promising technique for routing in W-MAN. Further, this approach has provided us complete information starting from the evolution of the said schemes to its final stages of development as in operation and in use today. Discussion about various spraying strategies shows thin and thick sides of each technique, node characteristics, mobility patterns, assumptions. This pin points possible investigation spaces and domains for further extension.

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