FUZZY-CONTROLLED POWER-AWARE PROACTIVE-ACKNOWLEDGEMENT BASED BROADCASTING (FP^{2}B) FOR MOBILE AD HOC NETWORKS

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ABSTRACT

Network-wide broadcasting is a fundamental operation for mobile ad hoc networks. In broadcasting, a source node sends a message to all other nodes in the network. Under ordinary flooding procedure, each node transmits the broadcast message to all of its 1-hop downlink neighbours, i.e. all nodes residing within its radio-range. Receiving the broadcast message all those downlink neighbours reply with an acknowledgement. Since in an ad hoc network a node may have multiple uplink neighbours, in ordinary flooding procedure, a node is supposed to receive the broadcast message from all those uplink neighbours and send acknowledgement to all of them, generating huge message contention and collision. This is popularly referred to as the broadcast storm problem. The present article is focused to remove the broadcast redundancy within 2-hop neighbourhood and beyond, as much as possible by prioritizing the 1-hop downlink neighbours of a node. Priority of a 1-hop downlink neighbour of a node n_i *increases if it is equipped with a large number of 1-hop downlink neighbours, large radio-range, high remaining battery power and very small number of uplink neighbours closer to the broadcast source than* n_i. n_i *waits a predefined amount of time to receive proactive acknowledgements from the 1-hop downlink neighbours having less priority. If it does not receive acknowledgement from those downlink neighbours within the waiting time, it sends the broadcast message to them. A fuzzy controller named Priority Assignor (PA) is embedded in every node that determines the priority of a 1-hop downlink neighbour. Simulation results firmly establish that the proposed protocol FP*^{2}*B produces high broadcast delivery ratio at much lesser message cost, compared to other state-of-the-art broadcast algorithms.*

KEYWORDS

Ad hoc network, broadcast redundancy, flooding, priority assignor, proactive acknowledgement.

1. INTRODUCTION

A mobile ad hoc network is a wireless network that is self-organized with many mobile nodes. No static infrastructure such as a wired backbone is available. All nodes are free to move around and the network topology may change frequently. Due to limited transmission range of wireless network interface, nodes are required to forward messages for those located outside the radio coverage, thereby forming a multi-hop network. Possible applications include emergency rescue in disaster situations, communication between mobile robots, exchanging information in the

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battlefield etc. [1-5]. Broadcast is useful in delivering messages to users with unknown location or group of users whom the source need not exactly know. Broadcast plays an important role in routing, network management etc. Many on-demand or reactive routing protocols (dynamic source routing (DSR) [2], ad hoc on-demand distance vector routing (AODV) [3], on-demand multicast routing protocol (ODMRP) [4] etc.) rely on broadcast to discover a route between two nodes or to update group status and multicast routes. Broadcast is also a viable candidate for multicast in ad hoc networks with rapid changing topology.

A density based innovative flooding (DBF) algorithm is proposed in [6]. In this algorithm, each node forwards a message based on its neighbour density and neighbour density of its previous node from which the broadcasted message. In a cluster of loosely couples nodes with few intermediate nodes as neighbours, the probability of forwarding the broadcasted message will be high. On the other hand, if a node is having high density of neighbours, then there will be lots of chances of packet collision at that point. Density based flooding tries to avoid that situation by assigning low priority at that point. The article in [7] proposes a tree based broadcast (TBB) method that maintains a spanning tree in the network. The algorithm is fully distributed, decentralized and resource-efficient. Broadcast operation is performed using a tree by forwarding the message not to all neighbours, but only those neighbours in the tree structure. Since the tree is acyclic, each message is received only once by each node, giving two advantages over the existing methods. Firstly it is needless to store the previous broadcasts in order to avoid endless multiplications of broadcast messages along a cycle of links. Only the originator of a broadcast message needs to store it and pay attention to whether its broadcast was successful or not if it is of great importance. Secondly, it is very economical considering how many times a broadcast message should be forwarded.

A reliable broadcast (RB) method is proposed in [8], which combines area based and neighbour-based technique of broadcast. Each node gains knowledge of neighbours and maintains neighbour list. The algorithm calculates the relative position of the nodes with respect to broadcast source node. The nodes that are farthest from the source rebroadcasts next. The algorithm tries to minimize the number of rebroadcasts by intermediate nodes and thus reduces message cost. Reference [9] proposes a method for reduction of broadcast traffic (RBT) in mobile ad hoc networks. It focuses on the fact that communication links in ad hoc networks break frequently due to node mobility. As the nodes move, a node receiving a packet on the boundary of communication range of a transmitter node is allowed to drop the packet, as the receiver may soon move out of the radio range of the transmitter. To approximate the distance between receiver and transmitter, receiver signal strength information is used.

The proposed algorithm FP^{2}B eliminates much more redundancy than these algorithms. It considers the then topological situation of the network up to 2-hop neighbourhoods of a node (in terms of the number and positions of uplink and downlink neighbours' w.r.t. the geographical locations of the broadcast source) , the radio-ranges and residual energy of involved nodes (this is very important from the point of view of ad hoc networks because there is no point to send the broadcast messages to the nodes which are about to be inoperable). All these greatly improve the network throughput by reducing the message cost through tackling the broadcast storm problem.

2. OVERVIEW OF FP^{2}B

According to the study of discharge curve of the batteries heavily used in ad hoc networks, at least 40% of total charge is required to remain in operable condition, the range from 40% to 60% is satisfactory, 60% to 80% is good whereas the next higher range is considered to be more than sufficient [13]. A node with residual energy 40%-60% will be termed as operational whereas a node with residual energy more than 60% will be called power-efficient in rest of the article. In

FP^2B, a node n_j drops a message immediately after receiving it from an uplink neighbour n_i at time t, provided its residual energy at that time is less than 40%. Otherwise n_j tries to find out a pair of 1-hop uplink neighbour and 1-hop downlink neighbours (n_i, n_k) of n_j at time t s.t. $n_j \in D_i(t)$, $n_k \in D_i(t)$ and $n_k \in D_j(t)$ where $D_i(t)$ denotes the set of 1-hop downlink neighbours of n_i at time t. In this situation, n_j won't send the broadcast message to n_k because n_k has automatically received that after n_i has sent the message. If all the 1-hop downlink neighbours of n_j at time t, are also 1-hop downlink neighbours of some uplink neighbour n_l of n_j at that time s.t. n_j has received the broadcast message from n_l, then n_j wont forward the broadcast message after receiving it. This eliminates the redundancy between 1-hop and 2-hop downlink neighbourhood of a node. But if there exists at least one 1-hop downlink neighbour of n_j that is not the 1-hop downlink neighbour of any uplink neighbour of n_j, then n_j will need to prioritize those 1-hop downlink neighbours. This is performed by a fuzzy controller named priority assignor (PA). Priority of a node n_k which is a downlink neighbour of n_j, depends upon its number of 1-hop downlink neighbours, radio-range, residual battery power, total number of power-efficient uplink neighbours (residual energy is more than 60%) and the number of power-efficient uplink neighbours that are closer to the broadcast source. n_j waits a predefined amount of time to receive proactive acknowledgements from the 1-hop downlink neighbours having less priority. If it does not receive acknowledgement from those downlink neighbours within the waiting time, it sends the broadcast message to them. The waiting time is equal to the amount of time that is required by n_j to forward (M_j-1) number of messages where M_j is the number of locations in message queue of n_j.

3. INPUT PARAMETERS OF PA OF n_a

Here it is assumed that n_a is an uplink neighbour of n_i at time t that is evaluating the priority of n_i at that time. Below I describe the input parameters of the PA of n_a.

Residual Energy Index

The residual energy index $\alpha_i(t)$ of n_i at time t is defined as,

$$\alpha_i(t) = 1 - e_i(t)/E_i \qquad (1)$$

Where $e_i(t)$ and E_i indicate the consumed battery power of n_i at time t and the maximum battery capacity of the same node, respectively. It is clear from the formulation in (1) that $\alpha_i(t)$ ranges between 0 and 1. Values of it close to 1 increase the priority of n_i as a downlink neighbour. It indicates that if n_i receives the broadcast message, then it is well-equipped from the point of view of battery power to forward it to its 1-hop downlink neighbours.

Radio-range Index

Assuming that R_{min} and R_{max} denote the minimum and maximum possible radio-ranges of the network, radio-range index rr(i) of node n_i is given by,

$$rr(i) = (R_i - R_{min} + 1) / (R_{max} - R_{min} + 1) \qquad (2)$$

where R_i is the radio-range of node n_i. From (2), it is evident that rr(i) ranges between 0 and 1. As R_i approaches R_{max}, rr(i) approaches 1. 1 is added to the denominator in (2) to avoid 0 value in the denominator when $R_{max}=R_{min}$. In order to maintain the fractional nature of radio-range index, 1 is added to the numerator also. High radio-range index of a node denotes that it has got high encapsulating capability. So, the number of its 1-hop downlink neighbours may increase any time.

Downlink Cardinality Index

The downlink cardinality index $\beta_i(t)$ of n_i at time t is defined as,

$$\beta_i(t) = (1 - 1/(|D_i(t)|+1)) \exp\ (1/(|D_i(t)|+1)) \qquad (3)$$

From the formulation in (3), $\beta_i(t)$ ranges between 0 and 1. Please note that 1 is added to $|D_i(t)|$ to avoid 0 value in the denominator when $|D_i(t)|=0$. Values of $\beta_i(t)$ close to 1 increase the priority of n_i as a downlink neighbour. It indicates that if n_i receives the broadcast message, then it may send that to a huge number of 1-hop downlink neighbours.

Uplink Cardinality Index

The uplink cardinality index $\gamma_i(t)$ of n_i at time t is defined as,

$$\gamma_i(t) = 1-\sqrt{(f1_i(t) \times f2_i(t))} \qquad (4)$$

$$f1_i(t) = (1-1/(|U'_i(t)|+1))\exp(1/(|U'_i(t)|+1))$$
$$f2_i(t) = (1-1/(|U_i(t)|+1))$$

Where $U_i(t)$ is the set of power-efficient uplink neighbours of n_i at time t and $U'_i(t)$ is a subset of $U_i(t)$ containing those uplink neighbours of n_i at time t which are closer to the broadcast source than n_a. 1 is added to both $|U_i(t)|$ and $|U'_i(t)|$ to avoid 0 value in the denominator in (5) and (6) when $|U_i(t)|$ and $|U'_i(t)|$ are 0. From the formulation in (4), $\gamma_i(t)$ ranges between 0 and 1. Values of it close to 0 decrease the priority of n_i as a downlink neighbour of n_a. It indicates that for n_i, n_a is not the only uplink neighbour from where it can receive broadcast message at time t, several other uplink neighbours are there. Priority of n_i decreases even more if some of those uplink neighbours are closer to the broadcast source than n_a.

4. RULE BASES OF PA

The range divisions of the parameters of PA are shown in table 1.

Table 1: Range division of parameters

Name of parameter	Range division	Fuzzy premise variables
α	0-0.40	A1
	0.40-0.60	A2
	0.60-0.80	A3
	0.80-1.00	A4
rr, β, γ	0-0.25	A1
	0.25-0.5	A2
	0.5-0.75	A3
	0.75-1.00	A4

Table 2 shows the fuzzy composition of α and rr producing a temporary variable t1. α is given more weight because high residual energy is indispensable for smooth operation of a node. Table 3 combines t1 and β generating another temporary output t2. The fuzzy combination of t2 and γ produces the ultimate output X of PA. If X=A3 or X=A4, then that downlink neighbour directly receives the broadcast message. Otherwise, the uplink neighbours wait for a specific amount of time (this time is equal to the time of receiving acknowledgement from the farthest downlink neighbour) before sending the broadcast message.

Table 2: Fuzzy combination of α and rr producing t1

α → **rr →**	**A1**	**A2**	**A3**	**A4**
A1	A1	A1	A2	A2
A2	A1	A1	A2	A3
A3	A1	A2	A3	A4
A4	A1	A2	A3	A4

Table 3: Fuzzy combination of t1 and β producing t2

t1 → **β →**	**A1**	**A2**	**A3**	**A4**
A1	A1	A2	A3	A3
A2	A1	A2	A3	A4
A3	A1	A2	A3	A4
A4	A1	A2	A3	A4

Table 4: Fuzzy combination of t2 and γ producing X

t2 → **γ →**	**A1**	**A2**	**A3**	**A4**
A1	A1	A2	A3	A4
A2	A1	A2	A3	A4
A3	A1	A2	A3	A4
A4	A1	A2	A3	A4

5. SIMULATION RESULTS

I evaluate the performance of FLB, using the network simulator ns-2 [10]. Except FP^2B, I implement the protocols tree-based broadcasting (TBB), reduction of broadcast traffic (RBT) approach, and density-based flooding (DBF). The simulation parameters are shown in table 5. The simulation metrics are broadcast cost (total no. of messages transmitted by all nodes in the network / (total no. of messages generated by broadcast sources × total no. of nodes in the network)) and packet delivery ratio ((total no. of data packets actually delivered / total no. of data packets actually transmitted) × 100). These are measured with respect to the total number of nodes in the network and total number of broadcast sources. The graphical results are illustrated in figures 1, 2, 3 and 4. When the measurements are performed with respect to the number of nodes, the number of broadcast cost is kept constant at 10. Similarly, when the measurement is performed with respect to the broadcast sources, the number of nodes is kept constant at 200.

Table 5: Simulation Parameters

Name of parameter	**Value**
Network area	500 m × 500 m
Number of nodes	50-300
Transmission range	10 m -50 m in first ten runs, 30 m – 100 m in second ten runs 10 m – 100 m in last ten runs
Packet size	128 bytes
MAC layer	IEEE 802.11g
Traffic type	Constant bit rate
Mobility model	Random waypoint
Bandwidth	1-4 mbps in first ten runs, 2-7 mbps in second ten runs and 3-10 mbps in last ten runs
Simulation time	1000 seconds

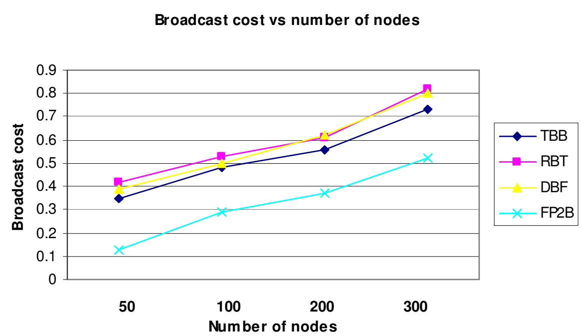

Figure 1: Broadcast cost vs number of nodes

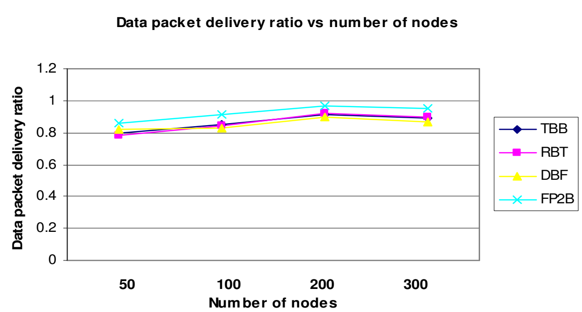

Figure 2: Data packet delivery ratio vs number of nodes

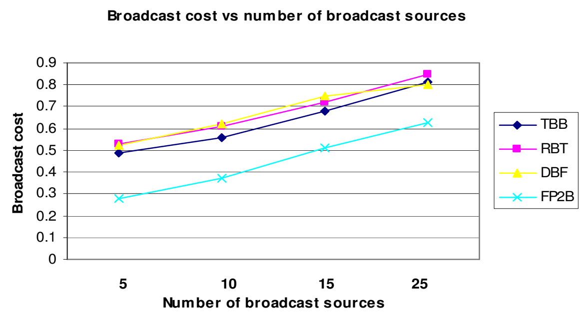

Figure 3: Broadcast cost vs number of broadcast sources

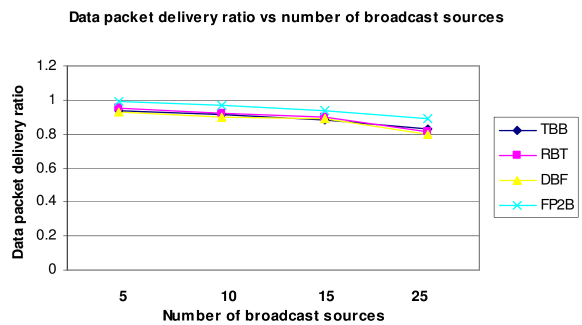

Figure 4: Data packet delivery ratio vs number of broadcast sources

Figures 1 and 2 measure the improvements produced by the proposed scheme in terms of broadcast cost and data packet delivery ratio with respect to the number of nodes whereas figures 3 and 4 measure the similar parameters with respect to the number of broadcast sources. It may be noted that the improved data packet delivery ratio produced by FP^{2}B is actually the result of much lesser broadcast cost that is produced by FP^{2}B compared to the others, due to less signal contention and collision. Broadcast cost for all the schemes increase when the number of nodes in the network increase or number of broadcast sources increase. The reason is that if the number of nodes in the network increases keeping the number of broadcast sources constant, then the number of recipients for each broadcast operation increase yielding a higher broadcast cost. On the other hand, if the number of broadcast sources increase then for each broadcast operation number of senders increase keeping the number of recipients constant. So, in both cases the broadcast cost increases and data packet delivery ratio decreases for all the protocols.

Since the proposed scheme FP^{2}B is power-aware, load-balanced and much more rigorous in decreasing redundancy than all other competitor protocols, the broadcast cost is much lesser in it than others. Less message cost generates less signal contention and collision increasing the data packet delivery ratio. As a result, the energy consumption in nodes decreases by a huge amount. This saved energy prevents some link breakages that take place due to complete exhaustion of battery of certain nodes. Therefore, the route-request messages that would have been otherwise injected into the network for repairing the broken links is not required in the proposed scheme.
Please note that in the proposed scheme redundancy is eliminated up to 2 hops. This improvement is significant from the point of view of today's wireless networks where the density of nodes is high, i.e. redundancy is high even if only 2-hop neighbours are considered. So, elimination of this redundancy saves a lot of broadcast cost as shown in figure 1.

It is seen from figure 2 that for all the protocols, the data packet delivery ratio increases with increase in the number of nodes due to better network connectivity until the network gets overloaded or saturated with nodes. But since FP^2B is more efficient than others in confronting the broadcast storm problem, it suffers least from the node overload as well as message overload due to a huge number of broadcast sources.

6. CONCLUSIONS

This paper presents a new approach for efficient broadcasting in mobile ad hoc networks. The proposed protocol called FP^2B is power and topology aware (up to 2 hops) and very efficiently reduces the cost of messages in the network by increasing the broadcast throughput. Design of the fuzzy controller *Priority Assignor* is based on real life observations and heuristics and it intelligently tackles the broadcast storm.

REFERENCES

[1] Anuradha Banerjee & Paramartha Dutta (2010), A Survey of Unicast Routing Protocols in Mobile Ad Hoc Networks", International Journal of Advances in Science and Technology, vol. 2, no. 10
[2] D David & B. Johnson.(1994), Routing in Ad Hoc Networks of Mobile Host. Proceedings of the Workshop on Mobile Computing Systems and Applications, pp. 158–163, IEEE Computer Society, Santa Cruz, CA
[3] Ian D. Chakeres et. Al (2005), AODV routing protocol implementation design", In Proceedings of 2nd International Workshop on Wireless Ad Hoc Networking, Notification (WWAN)
[4] Lee Sung-Ju, Su W. & M. Gerla,(1999), On-demand Multicast Routing Protocol (ODMRP) for Ad Hoc Networks
[5] Ho. C, Obraczka K & Tsudil G. (1999), Flooding for Reliable Multicast in Multi-hop Ad Hoc Networks, In Proceedings of 3rd International Workshop on Discrete Algorithms and Methods for Mobile Computing and Communications (DIAL M'99)
[6] N. Karthikeyan, V. Palanisamy & K. Duraiswamy (2010), Optimum Density Based Model for probabilistic Flooding Protocol in Mobile Ad Hoc Network, European Journal of Scientific Research, vol. 39 no.4, pp. – 577-588
[7] L. Tan, X. Zhan, J. Lie & F. Zhao (2006), A Novel Tree-based Broadcast Algorithm for Wireless Ad Hoc Networks", International Journl of Wireless and Mobile Computing, vol. 1 no. 2, pp. 156 – 162
[8] S.V.M.G. Bavithiraja & R. Radhakrishnan (2009), "A New Reliable Broadcasting Method in Mobile Ad Hoc Networks", International Journal of Computer Science and Network Security, vol. 9, no. 4, pp. 340-349, 2009
[9] A.Shukla (2007), On the Reduction of Broadcast Traffic in Mobile Ad Hoc Networks", In Proceedings of the International Conference on Wireless Communications, Networking and Mobile Computing
[10] http://isi.edu/nsnam/ns

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