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Fuzzy-controlled Scheduling of Real Time Data Packets (FSRP) in Mobile Ad Hoc Networks

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Abstract*—In ad hoc networks, the data packets can be mainly classified into two categories – real time and non-real time. Definitely the scheduling of real time data packets is going to be different from non-real time ones. The deadline of delivery is a very important criterion to be met in case of real time packets. The other requirements like velocity and energy concerns are enforced by the inherent dynamic nature of ad hoc networks. Sometimes it becomes completely unnecessary to forward a real time data packet when the deadline is impossible to meet or when the destination is on the verge of death. Also if the source nodes start sending real time packets at a very high rate, then it will not only increase congestion in the network but also hamper the forwarding of non real time packets since non real times have priority lesser than the real time packets. The present algorithm FSRP is designed considering all these factors and the performance improvement it produces is very significant compared to other state of the art scheduling protocols.

Keywords*—Ad hoc networks; delay; real time, route-request; scheduling.

Introduction

An ad hoc network is a collection of wireless nodes which form a temporary network without relying on an existing infrastructure or centralized administration. These networks are deployed mainly in emergency situations like battlefield, natural disasters like earthquake, floods etc. [1-5]. Many routing protocols have been proposed in ad hoc networks so far. In all of them, when the destination node is out of the radio-range of the source node the communication has to be multi-hop where some nodes act as router to bridge the gap between the source and destination nodes [6- 10]. If a node receives multiple message forwarding requests, it serves one of them and stores the others in its queue. The order in which these requests will be served is termed as a schedule. The job of a scheduler is to pick up that particular schedule that is expected to produce the best performance.

The choice of scheduling algorithm has a significant effect on the overall performance of the route, especially when the traffic load is high [10-14]. A packet scheduling scheme and algorithm called RACE [16] for real-time large scale networks was proposed which uses Bellman-Ford algorithm in order to find out ways with less traffic and delay. Earliest Deadline First (EDF) scheduling algorithm was used in RACE to transmit packets with shortest deadline. [16] presents the mostly used operating system of Wireless Network and differentiate them as Cooperative and Preemptive. Co-operative scheduling algorithms are based on Adaptive Double Ring Scheduling (ARDS) and EDF [10, 16], that has two queues with various priorities. Based upon the deadline of the arriving packets, the scheduler switches between the two queues. Cooperative schedulers are used in applications with limited resources. Preemptive Scheduling is based on EFRM scheme which is an extension of Rate Monotonic (RM) scheme. Dynamic multilevel priority (DMP) [16] is a scheduling algorithm that uses three different priority queues – a) real-time (Priority-1) b) non-real time data packets from lower level nodes (Priority-2) c) non-real time data packets present at the node itself (Priority-3). Shortest Job First (SJF) scheduler is used to process the non-real time data packets that are present at the same level priority. Time-Division Multiplexing Access is applied for the processing of data packets at different levels. For example, nodes that are situated at the lowest level and the immediate next lowest level can be allotted timeslots 1 and 2 respectively.

To the best of the author's knowledge, as far as the scheduling of real time data packets is concerned, there does not exist a scheme in the literature for ad hoc networks which consider the stability of routes and energy of the routers along with source and destination nodes. The present article focuses on proposing one scheduling scheme that will prioritize the real time message packets based on deadline, relative velocity between consecutive routers in the path along with their residual energies. The reason is that if a path is not stable enough in terms of energy and velocity, then real time packets should be urgently forwarded through those paths. Reason is that if the path is broken then a huge amount of time and energy will be wasted in the route discovery process to build a new path from that router to the destination. As a result, the packet may miss its deadline which is not at all affordable.

FSRP in Detail

As soon as a real time message packet generated by source n_s for destination n_d arrives at router n_i at time t, n_i first checks whether it is really possible to forward the data packet to the destination within the deadline. If it is impossible then the packet is dropped by $n_{i.}$

Let $D(P_{s,d}, i)$ be the time span required for a data packet generated at source n_s to travel to destination n_d from router n_i along the path P. P is the current path being followed by n_s to transmit packets to n_d in real time. Also assume that t is the current time and the real time packet which arrived at n_i, needs to be delivered to n_d within time t_d. If $(t+ D(P_{s,d}, i)) > t_d$ then the packet cannot be delivered to the destination within its stipulated time. As a result, the packet is dropped by n_i. According to the discharge curve of batteries heavily used in ad hoc networks, at least 40% of total charge is required to remain in operable condition. If at time t, the destination n_d is equipped with less than 40% of its total charge, then the current real time packet for n_d is dropped by n_i. Otherwise n_i forwards it. Decision to pick up one particular packet is taken by the real time fuzzy controller (RTF) which is embedded in every node. Like DMP, the scheduling process in FSRP is also non-preemptive.

Design of Real-time Fuzzy Controller (RTF)

The input parameters are deadline impact (LI), stability impact (SI) and source priority (SP). These are mathematically formulated in subsection A and combined in fuzzy rule bases in subsection B in this section.

Input Parameters of Real Time Fuzzy Controller (RTF)

The input parameters are described below:

i) $$LI(P_{s,d}, i) = (D(P_{s,d}, i)+t) / t_d \quad (1)$$

$LI(P_{s,d}, i)$ specifies the ratio of the estimated time at which the real time packet at router n_i is supposed to reach the destination n_d and the specified deadline t_d within which the packet must reach the destination. Definitely $LI(P_{s,d}, i)$ is less than or equal to one otherwise the packet would have been dropped. So the value of LI lies between 0 and 1. Higher the value of LI, higher is the urgency of forwarding the packet since the estimated time of arrival of the real time packet to n_d is very close to its deadline.

ii) $$SI(P_{s,d}) = 1 - [\sum_{n_j, n_{j+1} \in P_{s,d}} relv_{j, j+1}(t)\ eng_{j, j+1}(t)]^{0.5} / h(P_{s,d}) \quad (2)$$

Formulation of $relv_{j, j+1}(t)$ is illustrated based on figures 1a, 1b and 1c. n_j and n_{j+1} are two consecutive routers in $P_{s,d}$.

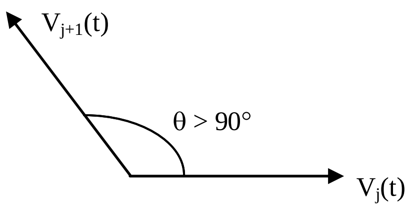

Fig 1a: The velocities make an obtuse angle

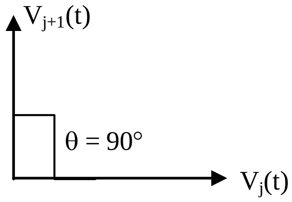

Fig 1b: The velocities make right angle

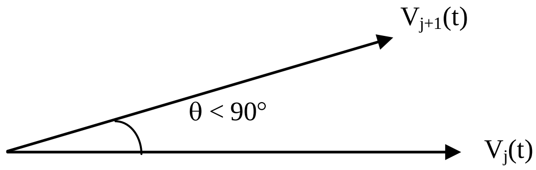

Fig 1c: The velocities make an acute angle

<u>For the situation in figure 1a</u>

Horizontal component of relative velocity $relH_{j,j+1}(t) = v_{j+1}(t) \cos(180° - \theta) + v_j(t) = v_{j+1}(t) \cos(\theta) + v_j(t)$

Vertical component of relative velocity $relV_{j,j+1}(t) = v_{j+1}(t) \sin(180° - \theta) = v_{j+1}(t) \sin(\theta)$

<u>For the situation in figure 1b</u>

Horizontal component of relative velocity $relH_{j,j+1}(t) = v_j(t)$

Vertical component of relative velocity $relV_{j,j+1}(t) = v_{j+1}(t)$

<u>For the situation in figure 1c</u>

Horizontal component of relative velocity $relH_{j,j+1}(t) = |v_{j+1}(t) \cos(\theta) - v_j(t)|$

Vertical component of relative velocity $relV_{j,j+1}(t) = v_{j+1}(t) \sin(\theta)$

$$relv_{j,\ j+1}(t) = \{relH_{j,j+1}(t)\ (1+ relV_{j,j+1}(t))\}^{0.5} / (1+v_j(t) + v_{j+1}(t)) \qquad (3)$$

$relv_{j,\ j+1}(t)$ specifies the relative velocity component of the link from n_j to n_{j+1} at time t. Similarly $eng_{j,\ j+1}(t)$ indicates the energy component of the same link at the same time. Assuming that $e_j(t)$ is the consumed battery power of n_j till time t and E_j is its total battery power, $eng_{j,\ j+1}(t)$ is formulated in (4).

$$eng_{j,\ j+1}(t) = \{(e_j(t) / E_j)\ (e_{j+1}(t) / E_{j+1})\}^{0.5} \qquad (4)$$

Lesser the value of $relv_{j,\ j+1}(t)$ lesser is the chance that the link between n_j and n_{j+1} will break soon in near future as a consequence of their movements. Similarly, lesser the value of $eng_{j,\ j+1}(t)$ less will be charge consumed by the involved nodes and high will be their remaining energies. As a result, less chance is there that the nodes will die soon or the link will break soon as a result of battery exhaustion of the two involved nodes n_j and n_{j+1}. $h(P_{s,d})$ is the number of hops in the path from n_s to n_d along the path P. Energy and relative velocity related components (eng and relv) have been averaged based on per hop basis.

From the formulation (2) it is evident that if the value of SI is small, there is high chance of link breakage in $P_{s,d}$ due to high relative velocity and/or scarcity of energy in routers and so, the real time packet should be sent urgently through this path. Please note that SI lies between 0 and 1.

iii) $$RY_{s,i}(t) = pk_{s,i}(t) / \left(\sum_{n_m \in F_i(t)} pk_{m,i}(t) \right) \quad (5)$$

$RY_{s,i}(t)$ specifies the priority of the source n_s to router n_i at time t. The priority decreases if n_s has already transmitted a huge number of real time packets to n_i for forwarding. The reason is that real time packets impose more thrust on the router to do its processing before the others. Therefore it also hampers forwarding of other packets. So, real time packets should not be transmitted in huge numbers unless it is utmost necessary. $F_i(t)$ is the set of all sources that transmitted real time packets to n_i for forwarding, till time t. $pk_{m,i}(t)$ is the number of real time packets transmitted by node n_m to n_i for forwarding till time t. From the formulation in (5) it is evident that $RY_{s,i}(t)$ lies between 0 and 1. Values close to 0 increase the priority of n_s to n_i.

Rule Bases of RTF

All three of LI, SI and RY range between 0 and 1. They are uniformly divided into crisp ranges. 0-0.25 is indicated as fuzzy premise variable a, 0.25-0.50 as b, 0.50-0.75 as c and 0.75-1.00 as d. Table 1 presents the fuzzy combination of LI and SI producing temporary output t1.

Table 1: Fuzzy Combination of LI and SI producing t1

LI → SI↓	a	b	c	d
a	b	c	c	d
b	b	b	c	d
c	a	a	b	c
d	a	a	a	a

High values of t1 correspond to the situation where LI is very high (d) and SI is very low (a). On the other hand low values of t1indicate the situation when LI is very low (a) and SI is very high (d). None of these parameters completely dominate one another. Table 2 shows the fuzzy combination of t1 and RY. It is quite practical that t1 dominates RY since t1 is the combination of two parameters (LI is concerned with the urgency with respect to the pre-specified deadline whereas SI is concerned with the fragility of the path i.e. how easily it can break; its good if the real time packets can be delivered through the path before it breaks otherwise a new route will have to be discovered that will greatly increase the cost of control messages injected into the network) both of which strongly contribute to determine the urgency of forwarding the message. High values of t1 contribute to increase urgency of forwarding whereas low values of RY encourage the router to urgently forward the message. The output produced by table 2 is UR. It is quite understandable that its value also lies between 0 and 1. It follows the same range distribution as the input parameters of RTF.

Table 2: Fuzzy Combination of t1 and RY producing t1

t1 → RY↓	a	b	c	d
a	b	c	d	d
b	b	c	d	d
c	b	b	c	d
d	a	b	b	c

Simulation Results

Simulation of the mobile network has been carried out using ns-2 [15] simulator on 800 MHz Pentium IV processor, 40 GB hard disk capacity and Red Hat Linux version 6.2 operating system. Graphs appear in figures 2, 3 and 4 showing emphatic improvements in favor of FSRP. Number of nodes has been taken as 20, 50, 100, 150 and 200 in different independent simulation studies. Speed of a node is chosen as 5m/s, 10 m/s, 25 m/s, 35 m/s and 50 m/s in different simulation runs. Transmission range varied between 10m and 50m. Used network area is 500m ×500m. Used traffic type is constant bit rate. Mobility models used in various runs are random waypoint, random walk and Gaussian. Performance of the protocols DMP-AODV, DMP-ABR and DMP-FAIR (DMP embedded versions of the protocols AODV, ABR and FAIR) are compared with their FSRP embedded versions FSRP-AODV, FSRP-ABR and FSRP-FAIR respectively. In order to maintain uniformity of the implementation platform, we have used ns-2 simulator for all the above-mentioned communication protocols.

The relevant simulation matrices are per packet (real time) waiting time per router in seconds vs number of nodes, percentage of real time packets that could be successfully delivered to their own destinations vs number of nodes and per node per session message cost vs number of nodes. Simulation time was 1000 sec. for each run.

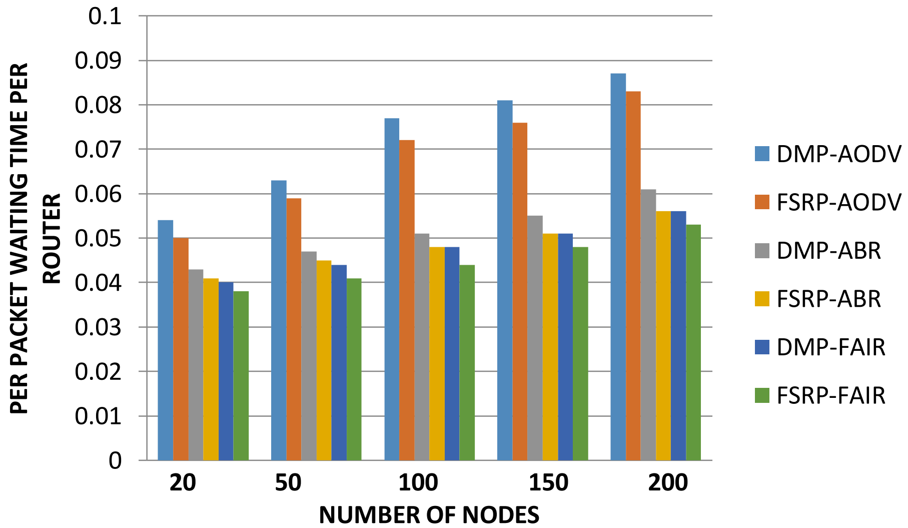

Figure 2: Graphical illustration of per packet waiting time per router vs number of nodes

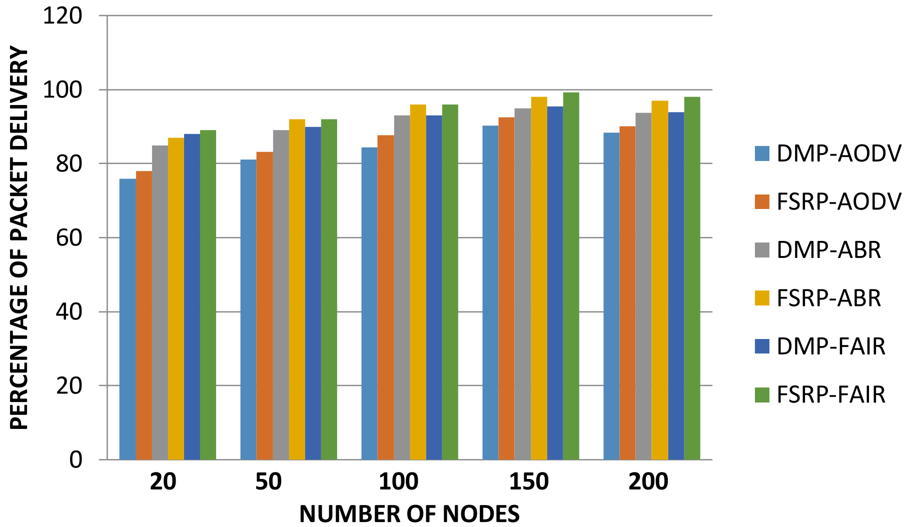

Figure 3: Graphical illustration of percentage of packets that could be successfully delivered to the destination vs number of nodes

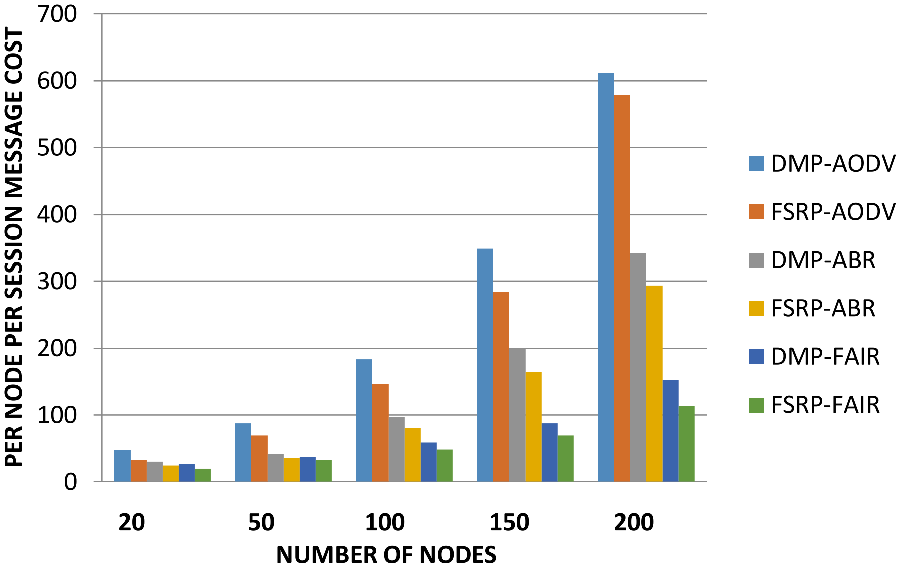

Figure 4: Graphical illustration of per node per session message cost vs number of nodes

Experimental Results

As the number of nodes continues to increase, more real time packets arrive at routers. If the scheduling method is not efficient, a lot of delay will be unnecessarily produced by the system where the average waiting time will increase. Although DMP [16] performs better than EDF , still it does not consider the factors like energy and relative velocity. The real time packets with short deadlines are prioritized and this is done in RTF through the input parameter SI. Also the packets for which deadline cannot be maintained, are unconditionally dropped by the router who discovers it first. This greatly saves the cost of messages in the network. FSRP estimates urgency to forward a packet based on its deadline, relative velocity between routers in the path being followed by the packet and the residual energies of those routers. If the residual energy of any one router in the path is poor, then the path may break up soon and for that a new route discovery session needs to be initiated by the current router. This results in the injection of a huge number of messages in the system increasing message cost. As a result, packet loss will increase due to severe congestion and packet collision in the network. FSRP considers all these aspects for which it produces much lesser message cost and high packet delivery ratio compared to DMP embedded versions of the state-of-the-art routing protocols in ad hoc networks like AODV, ABR and FAIR. This is illustrated in figures 3 and 4.

Due to the significant improvements in terms of message cost, delay in each router also decreases. The reason is that, if a route-request packet is being processed by a router and at that time a real time packet comes, then the packet will have to wait even if it has a very short deadline or travels through an unstable path in both DMP and FSRP due to the non-preemptive nature of both the protocols. But since the number of route-requests is much less in FSRP compared to DMP, the waiting time per router decreases for each packet. The non-preemptive nature of DMP is preserved in FSRP in order to minimize the number of context switches as much as possible because context switching has got its own overhead.

Although FSRP embedded versions of the protocols AODV, ABR and FAIR perform much better than their DMP embedded versions still the improvement is the maximum for AODV and minimum for FAIR. The reason is that FAIR as a protocol already consider the energy and relative velocity of routers to select the best path, although the formulations are much different compared to FSRP. So, FAIR, in rear cases, communicates through unstable paths.

Conclusion

Scheduling of real time data packets is a very important part in communication in ad hoc networks. If the average waiting time of these packets is decreased then automatically per node waiting time will decrease with great increase in the network throughput or packet delivery ratio. Unlike the previous scheduling algorithms, FSRP rightly considers the stability of the path in terms of relative velocity of the routers and their residual energies. Moreover, real time packets that cannot be delivered in time to the respective destinations are unconditionally dropped by the first router that discovered this. All these tremendously contribute to improve the performance of the underlying routing protocols.

REFERENCES

[1] C.E. Perkind & P. Bhagat,"Highly Dynamic Destination Sequenced Distance Vector Routing (DSDV) For Mobile Computers" *Computer Communications Review,* vol. 24 no. 4 1994, pp. 234–244.

[2] S. Murphy, J.J. Garcia-Luna-Aceves, "An Efficient Routing Protocol for Wireless Networks", ACM Mobile Networks and Applications Journal, pages 183-197, Nov.1996. http://citeseer.nj.nec.com/10238.html

[3] T.W. Chen, M. Gerla, "Global State Routing: A new routing scheme for wireless ad hoc networks" , *IEEE Conference On Information, Communication and Control, 1998*

[4] C.C. Chiang et. Al.,"Routing in clustered multi-hop wireless networks with fading channel", *IEEE Conference on Innovative Systems*. 1997, Singapore

[5] Broch, J., Maltz, D., Johnson, D., Hu, Y., , And Jetcheva, J. A performance comparison of multi-hop wireless ad hoc network routing protocols. In Proceedings of the Fourth Annual ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom '98) (Dallas, Texas, USA, Aug. 1998).

[6] A. Kodole, P.M. Agarkar, "A survey of routing protocols in mobile ad hoc networks", Multi-disciplinary Journal of Research in Engg. & Tech, vol.2 no. 1, pg – 336-341, 2015

[7] C.E. Perkins, E.M. Royer, "Ad Hoc On-demand Distance Vector Routing" *IEEE Wokshop on Mobile Computing Systems and Applications.*, 1999

[8] T.X. Brown, H.N. Babow & Q. Zhang, "Maximum Flow Life Curve for Wireless Ad Hoc networks" *ACM Symposium on Mobile Ad Hoc Networking and Computing*, USA, 2001

[9] C.K. Toh & P. Bhagwat, "Associativity based routing for mobile ad hoc networks", *Wireless Personal Communications, 1997,* vol. 4 no. 2., pp. 1-36

[10] A. Banerjee, P. Dutta, "Fuzzy-controlled adaptive and intelligent route selection (FAIR) in ad hoc networks", *European Journal of Scientific Research*, vol. 45 no. 3, 2010, pp. 367-382

[11] D.R.S. Victoria, S.S. Kumar,"Efficient bandwidth allocation for packet scheduling", International Journal of Future Computing and Communications, vol. 1 no. 4, Dec 2012

[12] C. Annadurai, "Review of Packet Scheduling Algorithms in Mobile Ad Hoc Networks", International Journal of Computer Applications, vol. 15 no. 1, Feb 2011

[13] A. Banerjee, P. Dutta, "Delay-efficient Energy and Velocity Conscious Non-Preemptive Scheduler (DEV-NS) For Mobile Ad Hoc Networks", International Journal of Advanced Networking and Applications, vol. 5 issue 4, 2014

[14] R. Parasher, Y. Rathi, "A-AODV: A modern routing algorithm for mobile ad hoc networks", International Research Journal of Engg. And Technology, vol. 2 issue 1, 2015

[15] http://www.isi.edu/nsnam/ns/tutorial/

[16] R.A. Kumar, K.A. Varshini, Multilevel Priority Packet Scheduling Scheme for Wireless Networks, International Journal of Distributed and Parallel Systems (IJDPS) Vol.5, No.1, May 2014

