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FUZZY LOGIC TECHNIQUE FOR GOSSIP BASED RELIABLE BROADCASTING IN MOBILE AD HOC NETWORKS

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ABSTRACT

Gossiping is the well-organized approach for information dissemination in Mobile Adhoc Network (MANET). In Gossiping approach, the node forwards packets with the probability known as retransmission probability. This probability must be chosen appropriately and effectively which is a challenging task. In this paper, we propose a fuzzy logic technique for gossip based reliable broadcasting in Mobile Ad hoc Networks. In this technique, each node computes the node velocity, residual energy and node degree. These inputs are passed through the fuzzy system and the fuzzified inputs are fed to the rule base system. Rules are constructed based on the intuitive that the rebroadcast probability at the nodes in sparser areas should be set high and that of at the nodes in denser areas as low. The outcome of fuzzy system defines the value for retransmission probability. Through simulations, we prove the proficiency of our technique which reduces the packet loss ratio and improves the network performance.

Keywords: *Mobile Adhoc Network (MANET), fuzzy system, Gossip Based Routing.*

1. INTRODUCTION

1.1 Mobile Ad hoc Networks (MANET)

An infrastructureless, group of wireless mobile nodes that forms short-range network dynamically is defined as the wireless adhoc network. [1] Typically, Mobile AdHoc Network (MANET) is a wireless network, which provides autonomous and multihop connectivity among mobile hosts. MANET is a decentralized network and changes its topology dynamically. [2] MANET includes a processor, memory, a wireless radio and a power source. [3] In addition, it is equipped with inadequate resources like power and bandwidth. When compare with wired networks, wireless networks has more merits and its own limitations. [4]

Lack of central controller allows a group of mobile nodes to communicate with each other and maintain connectivity among them selves. Military applications, sensor networks, crisis response, conference meetings and home, office networks, etc. are some of the applications of MANET. [5]

1.2 Gossip based Routing

Gossip algorithm is also known as probabilistic algorithm, where packets are transmitted based on the retransmission probability. The retransmission probability is also known as gossiping probability, which can also be fixed, dynamic or adaptive. Dynamic gossip scheme selects the probability based on the local information. In adaptive scheme, probability is adjusted based on the local network structure, coin tosses and the local response to the flooding call. [6] Gossiping protocols improves the reliability of the system. [7] Due to the advantages of flooding, the gossiping algorithm lessens the number of retransmissions. [8]

They take decision based on the repeatedly transmitted local information with a small set of peers and they are referred as epidemic protocols [9]. In peer communication, gossiping protocols are used to enhance the scalability [10]. In gossip-based protocols, the possible locations of destination are gossiped by the nodes [12]. By reducing the communication overhead, gossiping protocol proves that it is more efficient and scalable than flooding based routing protocols [13].

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Scalability, network load balancing, resilience to node failures, symmetric nature and simple low cost management are the qualities of gossip based protocols [14]. Because of these qualities, gossip based protocol is widely useful for peer sampling, ad-hoc routing, database replication, data aggregation, failure detection and reliable multicast [15].

MANET can use gossiping approach to tackle import design issues such as unreliable links, multi-hop connectivity, dynamic topology changes and adaptability. This protocol is highly hardness to failures [16]. Even though, gossiping protocol has many merits, there be existent some issues such as follows,

- Gossiping protocol can lead to a catastrophic failure when a lack occurs to meet the guarantee. This guarantee criterion differs for different applications [9].
- The combined feature of gossip routing protocol and flooding algorithm initiates broadcast storms. These storms bring peak number of collisions and could cause system failure [8].

1.3 Problem Identification

In our previous work, [27] we have developed a new gossip based broadcasting protocol. For the gossip-based broadcasting, we consider two probabilities p and q. Here p represents the rebroadcasting or gossiping probability and q represents the replication probability. p is estimated based on the network density and is dynamically adjusted in order to achieve both reduced rebroadcast and high reachability. The network density depends on the number of nodes and the node's connectivity in the selected area.

In this work, the retransmission probability p is generally based on node degree only, without considering other metrics like node velocity and residual energy, which have great impact on gossiping probability. To alleviate this shortcoming, in this paper, we propose to develop a fuzzy logic technique for gossip based reliable broadcasting in Mobile Ad hoc Networks.

The paper is organized as follows, section-2 includes related work, proposed solution is described in section-3, section-4 consists of simulation results and section-5 with conclusion.

2. RELATED WORKS

S.Rajeswari and Dr.Y.Venkataramani [8] have proposed an adaptive energy efficient and reliable gossip routing protocol for MANET known as AEERG. According to their approach, a counter is assigned to denote the number of neighbors at each node. The counter is kept in active state. Counter value is adaptively changed based on packet delivery ratio. In their protocol, the nodes can be in active mode with probability p or sleep mode with probability 1-p, which is fixed at the initial stage.

Weijia Jia et al. [11] have proposed a novel scalable and reliable multicast protocol based on clustering technique and gossip methodology. They have combined both Local Retransmission and Gossip-Based mechanisms (LRG) to provide high reliability of data delivery. Dynamical changes of gossip probability and gossip scope upgrade the spreading ratio of messages make the protocol adaptive to the rapid changes of network environment.

Keyvan Kashkouli Nejad et al. [12] have proposed a novel topology information retrieval scheme. By considering this scheme, they have also introduced an enhanced Hint-based Probabilistic Protocol. Their protocol is able to work efficiently under any network topology: nodes-density and coverage area size, and mobility. Instead of broadcasting extensive control packets for network topology information retrieval, their scheme carefully reuses the feedback information carried in unicast packets for this purpose without introducing any extra overhead.

Xuemei Gao et al. [17] have proposed a heuristic gossiping-based approach for routing in MANET. According to their approach, each node transmits packets with some probability. The probability is estimated based on the residual energy of a node, its velocity, and the information from its neighbor. Their heuristic gossiping mechanism facilitates to select appropriate nodes and thereby prevents redundancy, contention and collision caused by flooding. However, by their probability estimation technique we cannot compute accurate value for gossiping probability.

Advanced adaptive gossiping technique is proposed by Boto Bako et al. [18]. Their technique is able to adjust the dissemination probability dynamically and in a distributed manner. They have used the two-hop neighbor information to compute the value for gossiping probability. In their mechanism, each node periodically transmits hello

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message to discover two-hop neighbor information, the transmitted hello messages consists of neighbor table, which initiate more control overload. Further, they do not provide any mechanism for reducing packet losses.

Julien Haillot et al. [19] have introduced a new system for content-based communication. In their approach, information flows towards interested hosts rather than to specific set of destinations. Their approach is perfectly suitable for applications of information sharing, news distribution, service advertisement and discovery. In order to account for the absence of end-to-end connectivity in disconnected MANETs, they have considered the concepts of opportunistic networking and delay-tolerant networking.

Abdelmajid Khelil et al. [20] have developed an epidemic model for gossiping, which is a flooding-based probabilistic broadcasting technique. Their main objective is to postulate an adaptive broadcast algorithm for a wide range of MANET operation conditions. Their approach has mainly concentrated on reliable gossiping, a frugal and adaptive broadcasting technique. Their reliable gossiping specifies a simple mechanism for tuning the forwarding probability of gossiping depending on the local density of a node, reflected by the number of its neighbors. To provide fault tolerance in the network, they have also considered Collision, contention, frequent link breakage and network partitioning.

3. PROPOSED SOLUTION

3.1 Overview

In this paper, we propose a fuzzy logic technique for gossip based reliable broadcasting in Mobile Ad hoc Networks. Initially, afore transmitting data packet in gossip based broadcasting protocol, the node has to set appropriate retransmission probability (p) to the packets. Our technique assigns this gossiping probability using fuzzy logic system. According to this, each node calculates its velocity, residual energy and node degree. These inputs are made pass through the fuzzy system. The fuzzifier of fuzzy system constructs the membership functions for inputs and output. Rules are created in rule base system and the inference engine maps input to output. Rules are constructed based on the intuitive that the rebroadcast probability at the nodes in sparser areas should be set high and that of at the nodes in denser areas as low. Defuzzification is done using weighted-mean method. The node assigns retransmission probability (p) to the packets based on the outcome of fuzzy system.

3.2 Computation of Metrics

3.2.1 Residual Energy

Let E be the initial energy of a node and energy utilized by a node after time t is computed as [21]

$$E_n(t) = P_t * \eta + P_r * \mu \quad (1)$$

Where, $E_n(t)$ represents energy consumed by node n after time t, P_t is the number of packets transmitted after time t, P_r is the number of packets received after time t. η and μ are constants, it takes values between 0 and 1.

Using equation (1), we can estimate the residual energy of a node as follows,

$$E_{RE} = E - E_n(t) \quad (2)$$

3.2.2 Node Velocity

Consider α as maximum admissible speed of the node. The average speed of a node can be obtained by estimating cumulative value of last n movements. Then, the average speed is symbolized mathematically as below [22]:

$$avg\ S = D(t)/n$$

Where, D is the distance covered by the node at time t. This is can be represented as,

$$\text{Distance, } D(t) = \sum_{i=t-n}^{i=t} Dist_i \quad (4)$$

Equation (4) denotes the sum of distance covered by a node closing *i* seconds and t represent the current time. The mobility factor (MF) is defined as the difference between α and average speed of the node. MF is represented as follows,

$$MF = \alpha - avg\ S \quad (5)$$

From the computation of MF, we can conclude that larger MF exhibits slower node and conversely smaller MF indicates faster node.

3.3 Gossip Based Broadcasting Protocol Using Fuzzy Logic

For gossip-based broadcasting, let p be the gossiping probability or retransmission probability. This probability is estimated based on residual energy, node degree and node velocity. To estimate the gossiping probability (p) with more accuracy we use fuzzy logic.

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3.3.1 Fuzzy Logic

Fuzzy logic theory was commenced by Zadeh in 1960's and it is used as a tool for designing uncertainty of natural language. Fuzzy systems are well suited for approximate reasoning typically deals with mathematical models to make decision for incomplete or uncertain formulation [23].

The fuzzy engine includes inference system that consists of fuzzification, rule base and defuzzification components [24]. The schematic diagram of fuzzy logic is shown in figure-1 and basic components of fuzzy system are described below:

- ***Fuzzification***

Fuzzification represents the decisive input values in terms of the membership function of the fuzzy set.

- ***The Inference engine***

Succeeding the fuzzification process, the inference engine computes the fuzzy output based on fuzzy rules. Generally, fuzzy rules take if then rules.

- ***Defuzzification***

This component interprets the fuzzy output to the decisive value. The fuzzy output is derived using mathematical process.

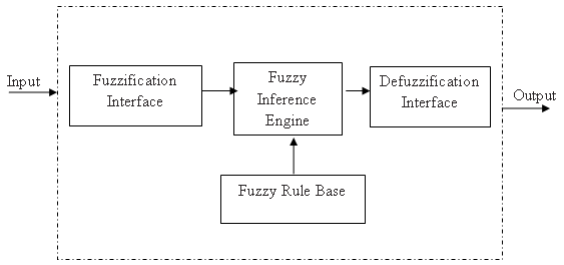

Figure 1: Fuzzy Logic System

3.3.2 Fuzzy Based Gossiping Probability Assignment Fuzzification

In the course of fuzzification, node degree (ND), residual energy (RE) and node velocity (NV) are taken as inputs. As a result of fuzzification and defuzzification process, we obtain retransmission probability (p) as the output variable. The input and output variables are qualitatively indicated as Low, Medium and High. The membership functions are represented across the range of input values. The member functions for node degree, residual energy and node velocity are picturized in figure 2a, 2b and 2c respectively. Figure 2d represents the membership function for output variable.

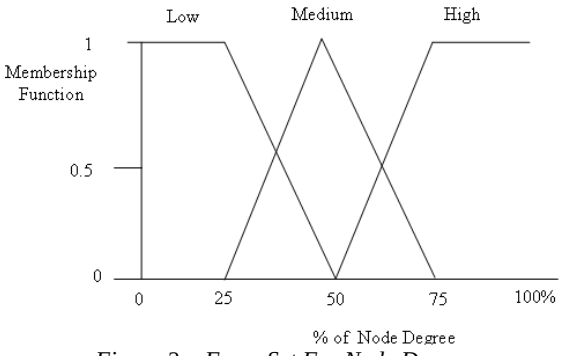

Figure 2a: Fuzzy Set For Node Degree

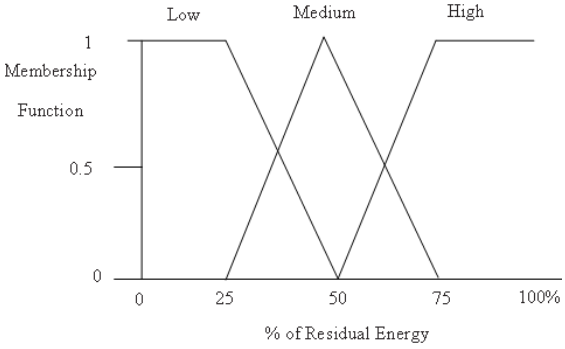

Figure 2b: Fuzzy Set For Residual Energy

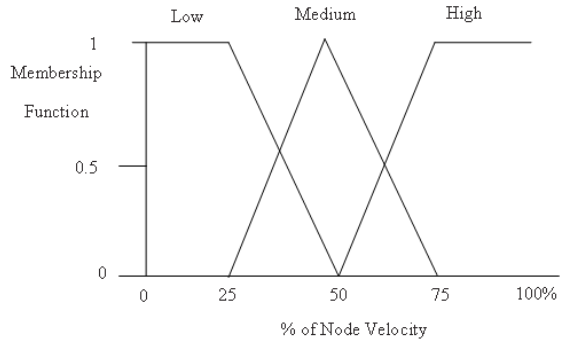

Figure 2c: Fuzzy Set For Node Velocity

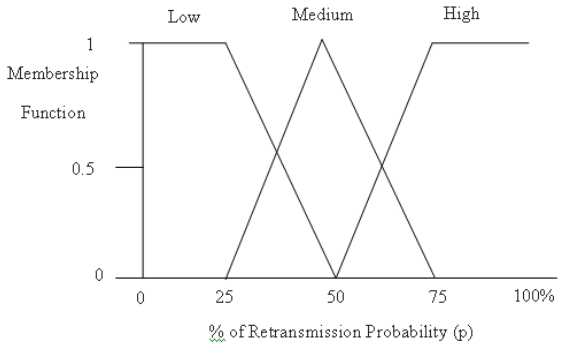

Figure 2d: Output Fuzzy Set

- ***Node Degree***

According to our previous work, the term node degree represents the number of neighbors

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surrounding a node. Further, the retransmission probability (p) greatly depends on node degree.

- ***Residual Energy***

Since, residual energy of a node has direct implication on data transmission; this metric is taken into consideration. Nodes with low residual energy may run out of the network soon and brings in retransmission circumstance.

- ***Node velocity***

The stability of the network is significantly affected by mobile speed. The node will move out of other's transmission range quickly according to its mobile speed. This mobility leads to link failure and thereby increase the retransmission of packets. Hence, we consider node velocity as an input variable for fuzzy set.

Rule Assessment

Rule evaluation defines the quality of fuzzy approximation. The inference engine of the fuzzy system is based on fuzzy rules. It maps input and output parameters to member functions of input and output. The fuzzy rule base fundamentally consists of set of if-then rules. Multiple inputs are connected using AND operator.

The rebroadcast probability at the nodes in sparser areas should be set high and that of at the nodes in denser areas as low. Our fuzzy inference system is designed based on 18 rules and they are described in table-1. Among 18 rules, we illustrate two examples as below,

Case (i)
If (NV =Low) && (ND = High) &&(RE = High)
Then
Retransmission Probability (p) is Low
End if
Case (ii)
If (NV = High) && (ND = Low) && (RE = Low)
Then
Retransmission Probability (p) is High
End if

In Case (i), the retransmission probability (p) is set to low, in view of the fact that, lower node velocity will not initiate more failures. In addition, nodes with high residual energy and node degree do not require more retransmission of packets.

Nodes with high speed will quickly move out of others transmission range and brings in more link failures. At the same time, low residual energy and node degree needs additional retransmission of data packets. Therefore, in case (ii), the retransmission probability is set to high.

Table-1 shows the fuzzy rule set of our approach. As explained case (i) and (ii), the remaining rules follow the same criteria.

Table 1: Fuzzy Rule Set

Rule	Node Velocity (NV)	Node Degree (ND)	Residual Energy (RE)	Retransmission Probability (p)
1.	Low	Low	Low	High
2.	Low	Low	Low	High
3.	Low	Low	Medium	Medium
4.	Low	Medium	Medium	Medium
5.	Low	Medium	High	Low
6.	Low	Medium	High	Low
7.	Medium	High	Low	Medium
8.	Medium	High	Low	Medium
9.	Medium	High	Medium	Low
10.	Medium	Low	Medium	Medium
11.	Medium	Low	High	Medium
12.	Medium	Low	High	Medium
13.	High	Medium	Low	High
14.	High	Medium	Low	High
15.	High	Medium	Medium	High
16.	High	High	Medium	High
17.	High	High	High	High
18.	High	High	High	High

Defuzzification

Defuzzification is the process of extracting representation value from the fuzzy set. There are different types of defuzzifiers. We have taken the weighted mean method; it is the most popular defuzzification method in fuzzy system. The defuzzification process is symbolized as follows [25]

$$P^* = \sum \eta_o(\overline{P}) * \overline{P} / \sum \eta_o(\overline{P})$$

Where, $\overline{P}$ denotes the centroid of each output member function and $\eta_o(\overline{P})$ is the strength of the output member function. P^* is the crisp value of output from defuzzifier.

The overall process of our fuzzy system is described in the following algorithm-1

Algorithm-1

Step-1

Node calculates its velocity (NV) (as per equation-3)

Step-2

Node measures its residual energy (RE) (as per equation-2)

Step-3

It also computes node degree (ND)

Step-4

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Before transmitting data packets, it passes NV, RE and ND through the fuzzy logic system

Step-5

The fuzzifier fuzzifies the inputs and builds member functions for input and output variables

Step-6

The inference engine maps the input and output to member functions using rule set

Step-7

The defuzzifier extracts the output from the fuzzy set

Step-8

Based on output value, the node sets retransmission probability (p) to the packet

4. SIMULATION RESULTS

4.1 Simulation Model and Parameters

NS-2 [26] is used to simulate the proposed algorithm. In our simulation, the channel capacity of mobile hosts is set to the same value: 2 Mbps. For the MAC layer protocol the distributed coordination function (DCF) of IEEE 802.11 (for wireless LANs) is used. It has the functionality to notify the network layer about link breakage.

In the simulation, mobile nodes move in a 500 meter x 500 meter region for 50 seconds simulation time. The number of mobile nodes is varied from 20 to 100. We assume each node moves independently with the same average speed. All nodes have the same transmission range of 250 meters. In our simulation, the speed is set as 2m/s. The simulated traffic is Constant Bit Rate (CBR). The pause time of the mobile node is kept as 10 sec. Our simulation settings and parameters are summarized in table 2.

***Table 2** Simulation Parameters*

No. of Nodes	20,40,60,80 and 100
Area Size	500 X 500
Mac	802.11
Radio Range	250m
Simulation Time	50 sec
Traffic Source	CBR
Rate	50,100,150,200 and 250kb
Mobility Model	Random Way Point
Speed	2m/s
Pause time	10 sec
Transmit Power	0.660 w
Receiving Power	0.395 w
Idle Power	0.035 w
Initial Energy	15.1 J
p value	0.4
q value	0.2

4.2 Performance Metrics

The proposed Fuzzy Logic Technique for Gossip Based Reliable Broadcasting (FL-GBRB) protocol is compared with the existing gossiping protocol [20]. The evaluation is mainly based on performance according to the following metrics:

Delay: It is the average End to End Delay.

Energy: It is the average energy consumption of all nodes in sending, receiving and forward operations.

Drop: It is the average number of packets dropped at each receiver.

Packet Delivery Ratio: It is the ratio of the fraction of packets received successfully and the total number of packets sent.

A. Based on Speed

In the simulation experiment, we vary the speed of the node as 5,10,15,20 and 25m/s keeping the number of nodes as 100.

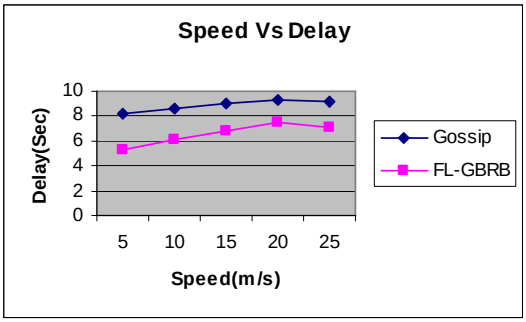

***Figure 3:** Speed Vs Delay*

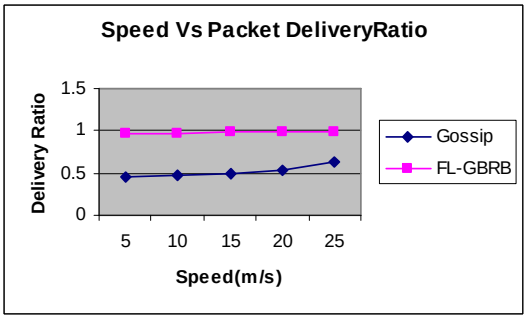

***Figure 4:** Speed Vs Delivery Ratio*

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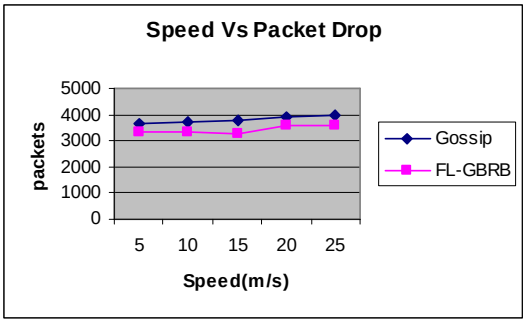

Figure 5: Speed Vs Packet Drop

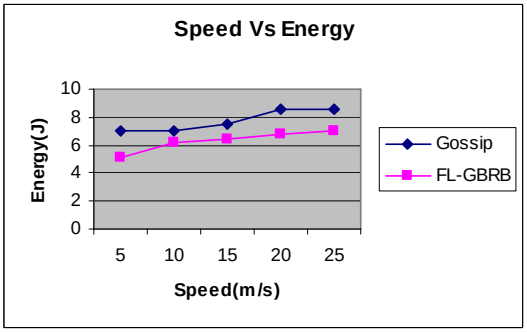

Figure 6: Speed Vs Energy

Figure 3 gives the delay of both the protocols when the speed is increased from 5 to 25m/s. As we can see from the figure, the delay is less in the case of proposed FL-GBRB protocol when compared with Gossip, since it chooses the retransmission probability based on velocity.

Since the broadcasting probability is adaptively adjusted depending on the connectivity in our proposed protocol, it results in increased packet delivery ratio with less packet drops. From Figure 4 and Figure 5, we can see that the FL-GBRB has increased packet delivery ratio and reduced packet drop when compared with the existing Gossip protocol.

Figure 6 shows the results of energy consumption when the speed of the node is increased. From the results, we can see that the proposed FL-GBRB protocol has less energy consumption than Gossip, since it reduces number of rebroadcasts.

5. CONCLUSION

In this paper, we have proposed a fuzzy logic technique for gossip based reliable broadcasting in MANET. In this technique, we assign the gossiping probability using fuzzy logic system. According to this, each node calculates its velocity, residual energy and node degree. These inputs are made to pass through the fuzzy system. The fuzzifier of fuzzy system constructs the membership functions for inputs and output. Rules are created in rule base system and the inference engine maps input to output. Rules are constructed based on the intuitive that the rebroadcast probability at the nodes in sparser areas should be set high and that of at the nodes in denser areas as low. Defuzzification is done using weighted-mean method. The node assigns retransmission probability to the packets based on the outcome of fuzzy system. Through simulations, we have proved the proficiency of our technique. Further, our technique reduced the packet loss and improved the packet delivery ratio when compared with existing gossip protocol.

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