

Overhead Reduction in Wireless Cellular Networks using Fuzzy Technology

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Abstract—The tremendous growth of wireless networks demands the need to meet different multimedia (audio, video, text, etc) applications available over the network. This application demand and allocation could lead to high overhead of data if the network has to maintain such a high resources for the Quality of Service (QoS) requirements of the applications. High overhead in communication networks occurs when too many packets, i.e., traffic, are contending for limited shared resources such as the bandwidth and buffer. If the bandwidth is not available or if the buffer in the base station is not available, then the data packets will be dropped. In such cases, the same data packets need to be retransmitted. This situation causes extra burden on the network. In our scheme, we propose such a framework for reducing the overhead in wireless multimedia network using fuzzy technology. The framework comprises design and development of new techniques and tools to address the above mentioned issue. In our scheme, we consider the channel condition between the source and the base station, and the availability of buffer at the base station in order to control the data flow within the network.

Keywords: Fuzzy Technology, Overhead Reduction, Channel Condition, Buffer Available, Management Factor.

I. INTRODUCTION

People use wireless networks to share data quickly either may be in a small buildings (office, home, etc) or across the world. Thus wireless network(ing) is defined as the technology that allows two or more computers to communicate, say to enable file sharing, printer sharing, internet connection, etc., using the standard protocols, but without the use of network cabling. These wireless networks are designed to support wideband data communications as well as multimedia communications. Hence these networks will be the basis for a wireless information society where access to information and information services like e-commerce is available to anyone, anywhere and at anytime.

We consider communication networks where computers or other similar devices are partly or exclusively connected with wireless communication links. Such networks have specific characteristic properties that compared with ordinary wire-based networks, are both advantageous and disadvantageous. Major disadvantages of the wireless communications include high error rate and bursty errors, location dependent and time varying wireless link capacity, scarce bandwidth, user mobility and power constraint of the hosts, etc, that do not exist in wired communication. Thus wireless networking is a tough task which has to address the above issues and challenges,

inorder to achieve the communication of information across the world by utilizing the network resources efficiently. The above difficulties in wireless network may occur due to mobility, disconnection, user interface, bandwidth allocation, buffer allocation, link delay, throughput, packet scheduling, error and flow control, frequency reuse and security. These difficulties are addressed by upcoming 3G and 4G wireless infrastructures by supporting broadband data applications and other new services, including multimedia applications that need real time guarantees.

Besides these protocols, there are many other issues that have to be addressed to provide improved QoS for wireless networks. One of the major issues in wireless networks is the overhead induced on the network due to retransmission of the dropped data packets. Data units are dropped mainly due to the non availability of various resources such as bandwidth, buffer, etc. This can be avoided by increasing the resources at the source node. But the source cannot increase the resource, i.e., bandwidth, since it has no control of resource allocation at the nodes, in which most data packets have to be dropped. Since bandwidth, buffer, etc., are critical in wireless network, these resources need to be used effectively by effectively transmitting data units and thus avoiding retransmission of the dropped ones. Thus the necessary step inorder to reduce the overhead is to design a simple and effective overhead reduction algorithm called overhead reduction in wireless multimedia networks using fuzzy technology. Hence in this approach, the base station reduces the overhead based on the buffer available at the base station and also the channel condition between the source and the base station as well as base station and the destination.

A soft computing tool called fuzzy technique is used to address the above discussed issue. It is a convenient way to map an input space to an output space, and is considered as the best way of mapping. The buffer available and channel condition are given as input to the fuzzy system which computes the tunable factor called management factor that decides the transmission or rejection of data and also the rate of transmission of data, thus reducing the possibility of dropping of data unit. Hence reducing the overhead on the network caused due to retransmission of the dropped packets.

This paper is structured into VI major sections, where section II explains the previous works related to fuzzy logic. Section III describes the proposed scheme that highlights the

overhead reduction in wireless multimedia networks using fuzzy logic which also includes the importance of fuzzy technology. The algorithm for the proposed scheme is also discussed. Section IV describes the simulation of the proposed work. Section V describes the simulation results. Section VI concludes with the paper and also gives the extension possibilities of our scheme.

II. RELATED WORK

Previously carried out works pertaining to fuzzy applications for wireless multimedia networks are briefly reviewed in this section.

In [1], a fuzzy call admission control scheme to meet the requirement of the QoS is discussed. Here it searches automatically the optimal number of the guard channels in a base station to make an effective use of resource and guarantee the QoS provision. A seamless handoff management protocol for next-generation wireless systems (NGWS) is proposed in [2]. The seamless handoff management protocol developed is a fuzzy logic-based adaptive handoff management protocol which is then integrated with an existing cross layer handoff protocol. A multi-sensor data fusion algorithm in Wireless Sensor Networks using fuzzy logic for event detection application is explained in [3]. In this method, each sensor node is equipped with diverse sensors (temperature, humidity light, and Carbon Monoxide). A new EDCA technique that adapts the Contention Window (CW) to channel conditions, which are ambiguous allowing the protocol to adjust its CW depending on the network utilization and performance therefore optimizing CW values so as to maximize network performance is proposed in [4].

The proposed work [5], proposes a fuzzy logic controlled protocol. In this protocol, the network traffic is estimated based on on-line channel sensing results, and the estimated network traffic then serves as a basis for tuning the size of the backoff window. The scheme in [6], presents a novel routing technique for ad hoc networks that applies fuzzy logic to differentiated resource allocation, considering traffic importance and network state. A model for fuzzy logic based congestion estimation within a proposed QoS architecture is presented in [7]. This architecture comprises of a QoS Management and QoS Control module which is implemented both at node level and at the sink for a system level QoS administration. A fuzzy logic approach to cluster-head node election is proposed in [8] which is based on three descriptors- energy, concentration and centrality. Studies in [9] evaluate the performance of Fuzzy Logic Congestion Detection (FLCD) algorithm in the wireless local area network environment and that performance is compared with the performance of ARED and the droptail mechanism.

In [10], a fuzzy-based dynamic channel-borrowing scheme (FDCBS) is presented to maximize the number of served calls in a distributed wireless cellular network by developing a method to predict the cell load and to solve the channel borrowing problem based on the fuzzy logic control. A fuzzy based priority scheduler for mobile ad-hoc networks

to determine the priority of the packets using Destination Sequenced Distance Vector (DSRs) as the routing protocols is discussed in [11]. There has been a significant focus on research challenges for fuzzy technology in [12], where a trust model using fuzzy logic in sensor networks is suggested. Studies in [13], presents a novel approach for designing a high performance QoS management scheme that exploits attractive features of fuzzy logic and provide adaptation to dynamic cellular environment. The proposed work in [14] presents a fuzzy-based packet scheduling scheme, where the fuzzy input parameters such as priority, time stamp and flow rate for each packet is considered to produce a scheduling factor. Depending on the value of scheduling factor the packet will be scheduled or unscheduled.

III. PROPOSED WORK

An effective technique of data management is proposed in this section that reduces the overhead and thus optimizing the QoS of the system.

A. Data Management

Effective transmission of data is still an unexplored problem in wireless multimedia networks. Data units in a network will be dropped in case of nonavailability of sufficient resources. Hence data units must be transmitted by using the resources effectively. Thus reducing the overhead on the network caused due to retransmission of the dropped frames. In order to reduce the overhead on the network, two resource parameters are addressed in this scheme, viz., buffer available in the base station for that particular user, and the channel condition between the source and the base station.

B. Fuzzy based Scheme for Overhead Reduction

Figure 1 shows the fuzzy based overhead reduction scheme consisting of a data manager, application database and fuzzy controller.

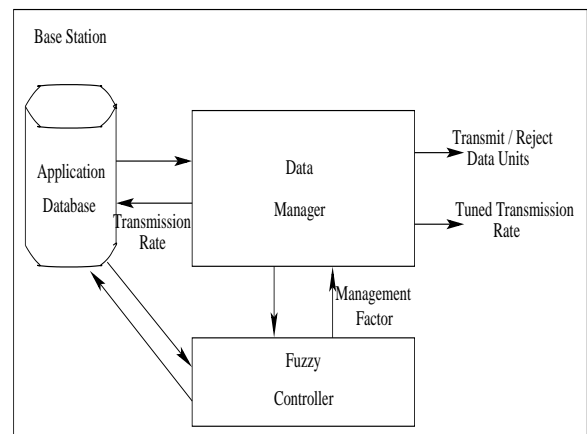


Fig. 1. Fuzzy based overhead reduction scheme

- **Data manager:** is one of the critical computational unit of base station, which controls the packet acceptance and

rejection. In our scheme, data manager uses a tuning factor called management factor which is computed using fuzzy controller. The management factor along with the transmission rate is used for the control of the data flow (equation 6) and thus improving the QoS of the system.

- **Application database:** is a dynamic unit consisting of data references of the calls on going, incoming and out-going. It consists of information like bandwidth required, bandwidth allocated, channel condition associated with each call, type of call, buffer available, and so on. This information is shared with the data manager and fuzzy controller. The application database is updated for every calculation of management factor.
- **Fuzzy controller:** is a soft computing tool used for considering multiple parameters. In our scheme we have considered two input parameters, viz., buffer available and the channel condition, and an output parameter called management factor.

C. Fuzzy Controller

A fuzzy controller used to compute management factor (shown in fig.2) consists of fuzzifier, inference engine, rule base and defuzzifier.

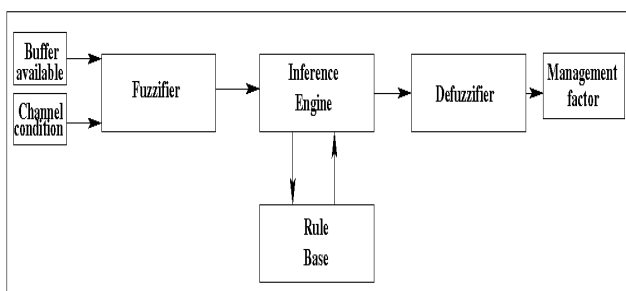


Fig. 2. Fuzzy Controller

- **Fuzzifier:** It is used for translating crisp inputs for each input variable i into linguistic values. The inputs in our scheme are buffer available and channel condition. For buffer available, its linguistic values $A^{(m)}$ $i, m = 1; 2; 3$ are (i) low, (ii) medium and (iii) high. Similarly for channel condition, its linguistic values $A^{(m)}$ $i, m = 1; 2; 3$ are (i) worst, (ii) moderate and (iii) best. The corresponding membership functions for all the inputs and output are shown in fig.3., where a medium (moderate) linguistic value is represented by triangular membership function, while low (worst) and high (best) linguistic values are represented by trapezoidal membership function.
- **Rule base:** The rule-base is a set of rules that emulates the decision making process of the human expert controlling the system. The rule is written in the form,
IF premise THEN consequent / action.

where premise is a combination of input linguistic values and consequent is what action to be taken. Because there are three linguistic values for buffer available and channel

Buffer available	Channel condition	Management factor
Low	Worst	Low
Low	Moderate	Medium
Low	Best	Medium
Medium	Worst	Medium
Medium	Moderate	Medium
Medium	Best	Medium
High	Worst	Medium
High	Moderate	Medium
High	Best	High

TABLE 1
FUZZY RULE BASE

condition, the number of rules is 9 (shown in table 1). In our scheme, the rule-base is in a form called functional fuzzy system.

- **Inference and Defuzzification:** After crisp inputs are mapped to the linguistic values through the membership functions in the fuzzification step, the inference rule is applied to determine the output by using the rule base. Once the management factor is determined from the inference step, the defuzzification is performed to obtain final management factor. The centroid method (also called center of area, center of gravity) is the defuzzification method used in our scheme which is given by the algebraic expression,

$$z^* = \frac{\int \mu_c(z).z.dz}{\int \mu_c(z).dz} \tag{1}$$

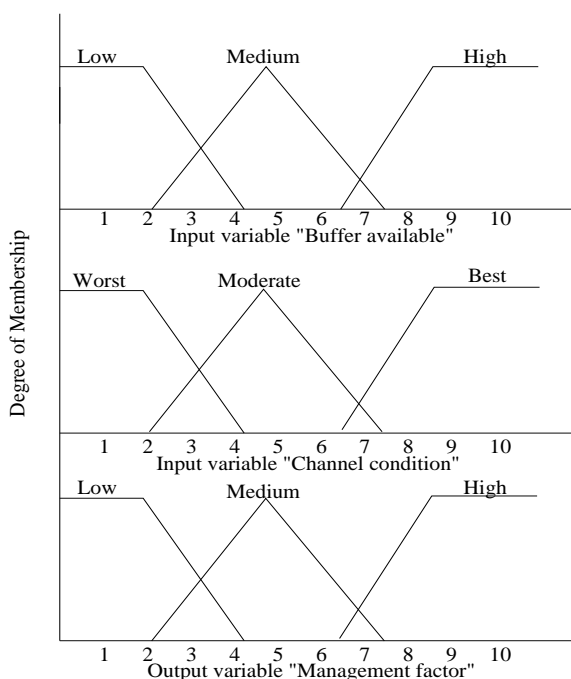


Fig. 3. Membership function for input and output linguistic parameters

D. Computing Adaptive Rate of Transmission

The output parameter of our scheme is a adaptive rate of transmission which tunes depending on the management factor. Transmission rate is the speed with which the packets travel from source to destination via their respective base station which is given by equation 5. In any wireless multimedia networks, consider terminal i uses the channel R_i times per unit time. Thus the information rate through the channel is given by

$$R_i f \left(\frac{\Gamma_i \cdot W}{R_i} \right) \quad (2)$$

We call it the effective data rate of user i. Here f is the highest rate in bits per channel use at which information can be sent with arbitrarily low probability of error. In other words f is the capacity of a discrete-time channel. W is the bandwidth of the channel. The total effective rate of all the data terminals R_T is simply the sum of them which is given as

$$ActualTransmissionRate, R_T = \sum_{i=1}^N R_i f \left(\frac{\Gamma_i \cdot W}{R_i} \right) \quad (3)$$

But, the problem arises when the buffer is not available at the base station. In such a case, the base station cannot be able to accept the packets at the same rate at which they are being transmitted by the source. Also there will be dropping of packets due to the unavailability of channel bandwidth. In both the cases there will be dropping of packets. Thus it is desirable to allocate the transmission rates to the user such that the energy used to transmit the information is minimized while keeping the errors under control. In our scheme these issues are addressed by transmitting the packets at a different rate which is given by,

$$AdaptiveTransmissionRate = \frac{R_T \times MF}{10} Mbps \quad (4)$$

E. Algorithms

Nomenclature: BA = Buffer Available, CC = Channel Condition, R_T = Actual Transmission Rate, MF = Management Factor, ATR = Adaptive Transmission Rate

Algorithm 1: Data Manager

BEGIN

- 1) Initialize values of BA, CC, R_T .
- 2) Call algorithm 2, to compute MF.
- 3) Data manager makes the decision based on the MF.
If $MF \leq Threshold$, then packets are not transmitted.
Else
Packets are transmitted at a adaptive rate given by,

$$ATR = \frac{R_T \times MF}{10} Mbps \quad (5)$$

- 4) The procedure is repeated for each packet.
- 5) The application database is updated for every computation of MF.

END

Algorithm 2: Computation of Management Factor

BEGIN

- 1) Assign membership values of BA and CC.
- 2) Membership values of BA and CC are given as input to the fuzzy tool in MATLAB (FIS).
- 3) Membership value of corresponding output of each rule is calculated using FIS.
- 4) Defuzzification method called centroid method is applied to get the output management factor which is expressed as

$$z^* = \frac{\int \mu_c(z).z.dz}{\int \mu_c(z).dz} \quad (6)$$

- 5) MF is given as input to the data manager that resides in a base station

END

IV. SIMULATION MODEL AND PERFORMANCE METRICS

We use a turbo C compiler on a Pentium IV processor to simulate our proposed scheme. A fuzzy logic toolbox of the MATLAB is used to compute the management factor based on the rules defined (discussed in Section 3).

A. Network Environment

The network environment considered in our scheme consists of N number of mobile nodes communicating with each other through a single base station (a single cell structure). Assumptions are made that all the mobile nodes are perfectly placed under the coverage area of the base station. Handoff procedure cases are ignored here. The network model is shown in figure 4. For example, we consider node 1 as the source and node 6 as the destination.

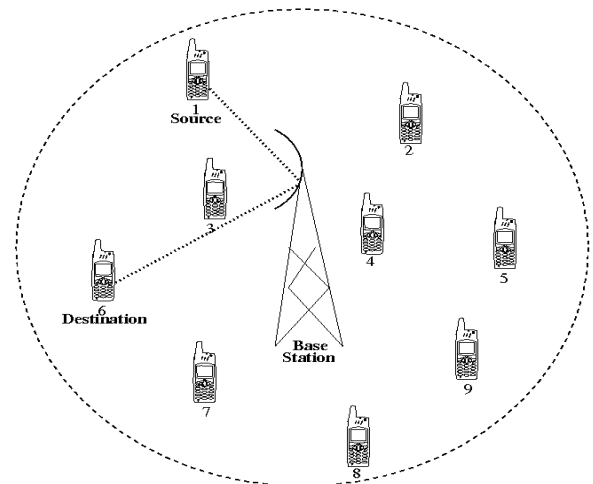


Fig. 4. Network environment

B. Simulation Inputs

The simulation input parameters used in evaluating the performance of our proposed work are tabulated in table 2.

Parameter	Value
Number of Mobile nodes, N	100
Number of base stations	1
Maximum buffer size	10 Mega bytes
Fixed buffer available	1, 3 and 6
Fixed channel condition	1, 3 and 7
Threshold value	2 (Fuzzy value)

TABLE II
SIMULATION INPUTS

C. Fuzzy Model

The input parameters used for simulation are buffer available and channel condition. Channel condition is a weighted sum of various parameters like type of channel, fading mechanism, bandwidth allocated, etc. Both the input parameters values are scaled to 0 to 10 using fuzzy inference rule. Each input parameters are defined with three membership values such as low/worst, medium/moderate and high/best. For buffer available, its linguistic values are low (0 to 4), medium (2 to 7) and high (6 to 10). While for channel condition, its linguistic values are worst (0 to 4), moderate (2 to 7) and best (6 to 10).

The output parameter management factor (MF) varies in the range from 0 to 10. Similarly it is also defined with three membership variables (linguistic values). The linguistic values of management factor are low (0 to 4), medium (2 to 7) and high (6 to 10).

D. Simulation Procedure

Each of the simulation executes at varying time interval. The simulation procedure is as follows,

Begin

- Generate a WMN consisting of N number of mobile nodes that communicate with each other through a single base station.
- Setup a communication path between source and destination.
- Size of the data unit is decided that will be transmitted from source to destination.
- The management factor is computed using the fuzzy toolbox of the MATLAB.
- The input to the fuzzy controller are buffer available and the channel condition.
- All the possible input/ output combinations are computed using the rule base editor of the FIS.
- All the combination of input/output values are dumped into the database of the compiler using IF-THEN rules.
- The input to the data manager is the management factor, which decides the acceptance or rejection of packets.

If $MF \leq$ threshold, block the sending of data units
Else

Transmit the packets at the rate given by equation

5

- The simulation is repeated for each packet in order to compute the percentage of data units that are successfully transmitted.

End

E. Performance Metrics

The various network performance parameters considered in our scheme are as follows,

- **Management Factor:** It is the defuzzified output of a fuzzy controller. Based on the value of management factor, the data manager decides whether to transmit the packets or not, along with the transmission rate of the packets, if any.
- **Percentage of transmission rate tuning:** It is defined as the ratio of the adaptive transmission rate of packets to the actual transmission rate of packets.
- **Percentage of successful transmission:** It is defined as the ratio of number of packets that are successfully transmitted to the total number of packets that are to be transmitted.
- **Percentage of packets dropped:** It is defined as the ratio of number of packets being dropped (due to low management factor) to the total number of packets that are to be transmitted.

V. RESULTS

The results that we obtained as a consequence of using the above stated approach one can clearly demonstrate the worthfulness of adopting fuzzy approach for reducing the overhead in wireless multimedia networks. Further we show that by adopting the fuzzy approach, the packets can be effectively transmitted from source to destination.

By observing the fig.5, we can notice the variation of management factor for different simulation interval.

Fig.6, shows the change of transmission rate (called as the percentage of transmission rate tuning) for different simulation rate.

Fig.7, shows the number of packets being successfully transmitted for different cases of buffer availability.

Fig.8, shows the number of packets being successfully transmitted for different cases of channel condition.

Fig.9, shows the number of packets being dropped for different cases of buffer availability.

Fig.10, shows the number of packets being dropped for different cases of channel condition.

VI. CONCLUSIONS

Our scheme of reducing the overhead in wireless multimedia networks using fuzzy technology has achieved reduced dropping and increased packet transmission at different capacity of buffer and channel conditions.

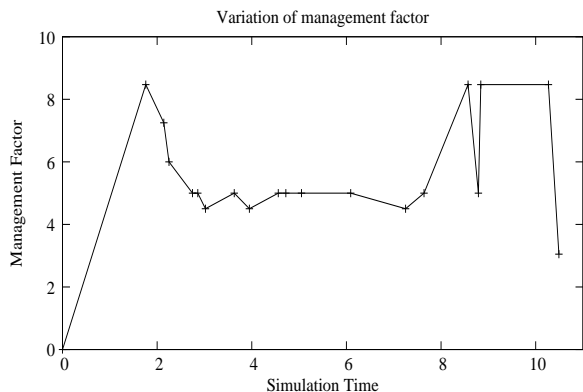


Fig. 5. Management factor V/s. Time

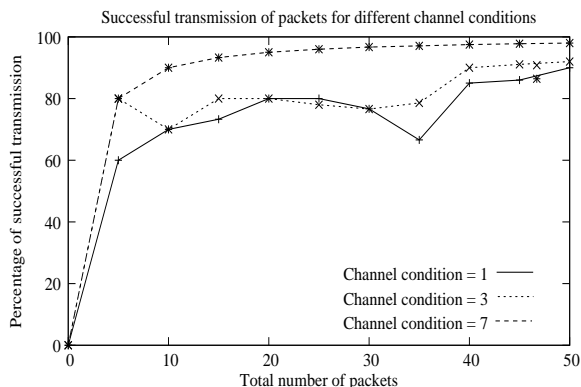


Fig. 8. Successful transmission rate for different channel condition

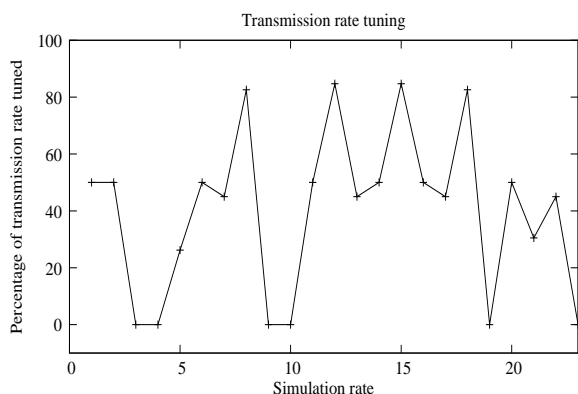


Fig. 6. Tuning of transmission rate

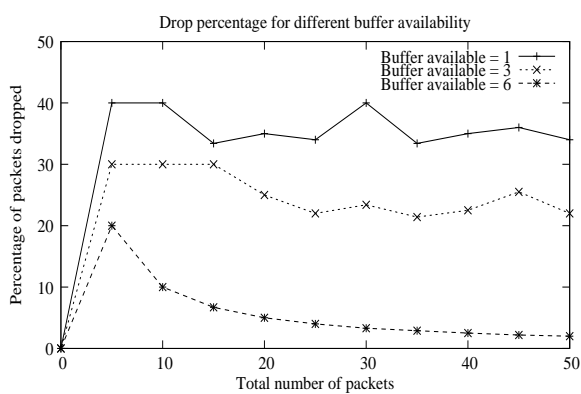


Fig. 9. Dropping of packets for different buffer availability

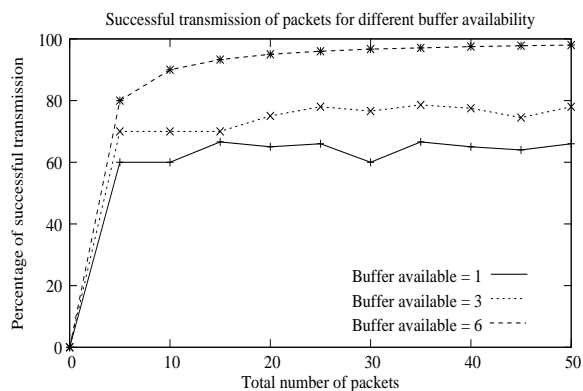


Fig. 7. Successful transmission rate for different buffer availability

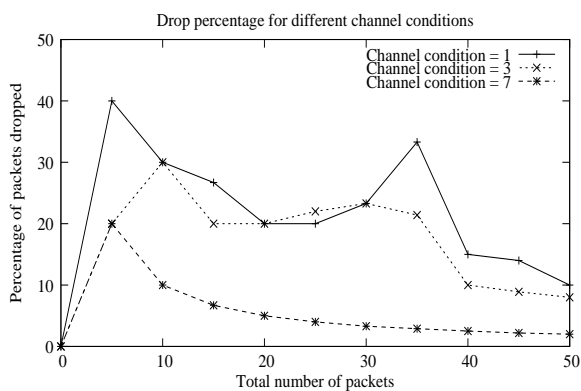


Fig. 10. Dropping of packets for different channel condition

The packets sometimes will be dropped because of various reasons. Some of the reasons addressed in our scheme are the non availability of the buffer and the poor condition of channel. One important characteristic of our scheme is that the packets are not completely blocked when the channel condition and buffer availability are medium, instead they are transmitted at a different rate of transmission which might be less than the

actual transmission rate. Extensive simulation results reveal that packets are successfully transmitted at higher availability of buffer and better channel conditions.

VII. ACKNOWLEDGMENT

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