A Study on Dynamic Estimation Algorithm for the CATV/LAN network

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ABSTRACT : In this paper, we proposed the MAC protocol and analyzed the performance for CATV/LAN network which was based upon HFC network increased abruptly as an alternative method of high speed network. Upstream channel analyzed very deeply for CATV/LAN network has the preferential access property depending upon that position and unidirectional property. To solve this problem, we propose the CSMA-CD/U/P protocol that data packet is transmitted as Pi probability when it is occurred. Also, we proposed dynamic algorithm of updating the Pi and performed wide simulation in various environments.

요약 : 본 논문에서는 초고속 통신망의 한 대안으로 떠 오르고 있는 HFC망을 기초로 한 CATV/LAN의 MAC프로토콜을 제안하고 분석한다. CATV/LAN망에서 상향 채널은 위치에 따라 다른 우선적인 접속 특성을 가진다. 이런 문제점을 해결하기 위하여 전송할 데이터 패킷이 발생하더라도, 그 즉시 전송하지 않고 확률적으로 전송하는 새로운 프로토콜을 제안한다. 또한, Pi값을 동적으로 갱신할 수 있는 알고리즘을 제안하고, 이에 따른 광범위한 시뮬레이션을 수행한다.

1. Introduction

The use of data communication and internet communication has been increased abruptly according to the development of personal computer and mammoth extension of information equipment. Also, all kinds of data become various types such as image data, voice data, and MPEG data beyond existing character-type data and it is necessary to construct the highspeed communication infrastructure which is focused upon the real-time data. The high speed networks are recently known as the very main social overhead capital preparing information epoch and have already extensively studied among advanced nations. A basic technique of high speed communication network is expected to use optic fibers and ATM(asynchronous transfer mode). However, it is essential to alternate the conventional ideas owing to the high cost of optic fiber and long time for high speed network infra-construction. Accordingly, digital subscriber line(xDSL) method using the copper-wire and CATV/LAN is recently highlighting the alternatives of existed network. Especially, among these networks, CATV/LAN network are very extensively studied. We should call the extended CATV/LAN network by interconnecting PSTN, ATM and Satellite network[1].
These kinds of services using the CATV/LAN network is video on demand, effective telecommuting, remote learning, teleshopping, ever-increasing on-line newsgroup, web surfing, remote game playing, PACS system, and teleconferenceing. Especially, the Cable modem technique is already studied by Motolora, GI, Com21, Lucent Technology and Zenith. the standardization of CATV/LAN by DAVIC, ATM Forum, IETF and IEEE 802.14

Working Group is also under way. The topology of CATV/LAN network is typically composed of tree and branch structure. Also, for spectrum distribution, in order to maintain compatibility with the today's analog CATV channels, the spectrum of 400MHz bandwidth between 40-450MHz bandwidth is not going to be affected by the new services. The spectrum of 40MHz bandwidth between 5MHz and 45MHz will be used for upstream channel from these to the rest of the world while the spectrum of 300MHz bandwidth between 450MHz and 750MHz should be used for downstream channel. The upstream channel in CATV/LAN is subdivided by N-RF channels which have the transmission bandwidth of 1-6MHz. Accordingly, the downstream channel is from the headend to subscribers use the modulation method of 64QAM, and 256QAM and provide transmission speed of 30 - 40Mbps but the upstream channels from subscribers to headend use the modulation method of QPSK, and DWMT and provides data packet transmission speed of 2-10Mbps.

The MAC protocol of CATV/LAN network published IEEE 802.14 draft basically consists of the reservation method and slotted method but its standardization is not confirmed. Slotted-type protocols have some difficulty for ranging process which is maintained the synchronization between headend system and station and the high cost of hardware, very big size. Also, it occurs the internetworking problem of ATM network and difficulty of network extension for some short time and allocation of bandwidth and quality of various services according to several data traffic. Also, the CATV/LAN network has basically the preferential-access property and unidirectional characteristics according to the location of stations and its protocol is necessary to adopt random access protocols for network.

In this paper, we proposed the new MAC protocol, CSMA-CD/U/Pi(unslotted Pi-persistent CSMA/CD) that it is transmitted with the probabilistic Pi value. Also we obtained the proper Pi to get the network's fairness.

2. Description of CSMA-CD/U/Pi Protocol and Dynamic Estimation

We called unslotted Pi-persistent CSMA-CD as the CSMA-CD/U/Pi protocol in this paper. The total CATV/LAN network is shown in Fig.1 in detail and its modeling consists of M $(1 \leq M \leq \infty)$ stations, each of which is assumed to have an infinite storage buffer. Upstream data packets with generally distributed transmission time T_T are arrived at each station according to Poisson process with rate λ. Depending upon the position of a station on the upstream channel in the CATV/LAN network, the station is assigned a unique station number $i\ (= 1, 2, \cdots, M)$. Under the CSMA-CD/U/Pi protocol, any backlogged station sensing the idle state of the upstream channel begins transmission with Pi value and listens to the activity of its upstream channel. If the station detects its upstream data packets, it promptly defers transmission with (1-Pi).

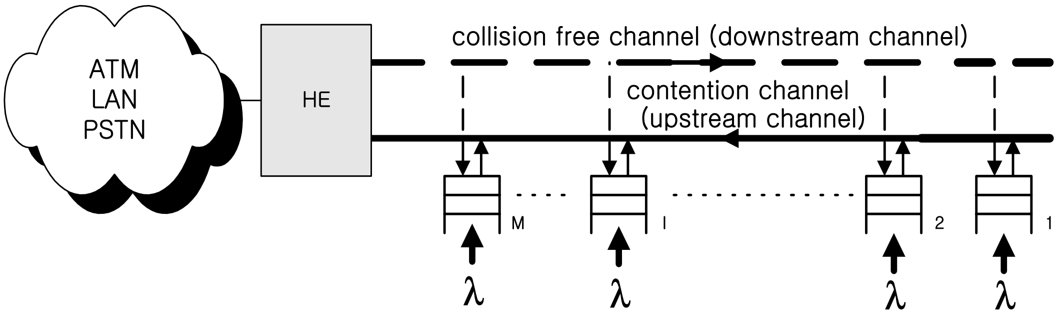

Fig. 1 Modeling of the CATV/LAN network under CSMA-CD/U/Pi

We assume that r_i is the probability that upsteam channel located the CATV/LAN network is empty when station transmits data packet arrived at buffer queue. And we assume that σ_i is the probability that upstream channel is empty and station i can transmit data packet when data packets are arrived at buffer queue. We also assume that c_i is the probability being not occurred the data packet collision during their transmission through the CATV/LAN network. For the simplicity of analysis, c_i must be considered as unity which its meaning is not always occurred between data packets.

$$\sigma_i = r_i \cdot P_i \cdot c_i \tag{1}$$

where i is an arbitrary station. Also, we assume that the d_L $(L = 1, 2, 3, \cdots)$ is the time from being arrived at the L-th data packet at buffer queue of CATV/LAN network to transmit that packet. Random variable d_L is independent each other and is distributed geometrically with probability variable σ_i. Thus, we can obtain the following equation.

$$\Pr[d_L = k, \ k \geq 1] = (1 - \sigma_i)^{k-1} \sigma_i \tag{2}$$

In the equation (2), we can obtain the first two moments respectively as

$$E[d_L] = 1/\sigma_i ,$$

$$E[d^2_L] = (1 - \sigma_i)/ \sigma^2_i . \tag{3}$$

Also, the z-transform of d_L is obtained as the following.

$$d_L(z) = \frac{\sigma_i}{1-(1-\sigma_i)z} \tag{4}$$

Accordingly, an average transmission delay of arbitrary station i is equal to an arbitrary station j if the fairness problem of CATV/LAN network is satisfied. That is, it is necessary to satisfy the same condition as the $E[d_i] = E[d_j]$. We can obtain the dynamic P_i equation to provide the fairness of CATV/LAN network.

$$P_i = (1 - \sum_{j=1}^{M-1} \lambda_j) \cdot c_M \ / \ (1 - \sum_{j=1}^{i-1} \lambda_j) \cdot c_i \qquad (5)$$

where i, j is an arbitrary station and it is noted that the condition of stability must satisfy $\lambda_i < \sigma_i$. We may carefully propose the dynamic P_i algorithm. Therefore, it is necessary to dynamically alter the P_i in response to changing of traffic conditions. In a distributed system such as the one being considered here, it is not possible for each station to precisely know the arrival rates at all of the other stations. However, since each station can sense all of the traffic on the upstream channel, it can approximate these rates by estimating the traffic from each station on the upstream channel as a percentage of the total traffic. Each station knows its relative position in the upstream channel, and from the channel activity it can also determine the number of active stations. The dynamic algorithm is called free-weighted estimation algorithm and includes two design parameters, β and K. Each station i continuously updates its P_i according to every β unit of time. Also, we may estimate their arrival rates by analyzing arrival rate patterns of each station based upon estimation window, η.

3. Simulation Results and Discussion

In this section, we show the adaptive characteristics of proposed algorithm which obtain dynamic P_i value according to the throughput. We assume that the number of CATV/LAN network consist of $M = 5$, each of which has an infinite storage. Also, Data packets with generally distributed transmission T_T are arrived at each station according to Poisson process with rate λ. We assume that propagation delay time is unity. This mechanism is updated by measuring the arrival rates during estimation window η, in terms of each updating time, β. Also, we assume that arrival data packets are symmetric and this system still maintains fairness of the CATV/LAN network. We fulfil the analysis and simulation under various network environments for the proposed dynamic estimation algorithm. This algorithm has to take up the design parameters that it is the β and K for free-weighted estimation algorithm. Also, we assume that the MDS has unity probability value, that is, the most downstream station may transmit promptly whenever the data packets is arrived at buffer queue of station located the CATV/LAN network.

Free-Weighted Estimation Algorithm

- *Step 1 : Monitor channel. If* $t = n\beta$, *n=1,2,3,....... go to setp 2.*
- *Step 2 : Determine window of estimation* $\eta = Min(K\beta, t)$

  where $K \geq 1$ *(possibly an integer).*

  Determine the number of active stations M and own index i.

  Count $\eta_i =$ *number of packets transmitted by Stations i in time* $(t-\eta, t)$, $\forall_i$.

  Estimate $\Lambda_{est}(i)$ = *estimate of* $\lambda_i = \eta_i / \eta$, $\forall_i$.

  Estimate Λ_{est} = *estimate of* $\Lambda = \sum_{i=1}^{M} \lambda_i$.
- *Step 3 : Computer* P_i *by the equation depending upon the fairness criterion being used.* $P_i = (1 - \sum_{j=1}^{M-1} \lambda_j) \cdot c_M / (1 - \sum_{j=1}^{i-1} \lambda_j) \cdot c_i$,

  or $P_i = (1 - \Lambda + \lambda_M) \cdot c_M / (1 - \sum_{j=1}^{i-1} \lambda_j) \cdot c_i$.
- *Step 4 : Adjust* P_i *dynamically for the CATV/LAN network.*
- *Step 5 : and then go to step 1.*

In Fig.2, we show the adaptive P_i characteristics according to the network throughput and traffic of stations is assumed by equal distribution, that is, $\lambda_i = 0.1$. As the result of exact analysis, all of the stations have their P_i converged to the acceptable range of the identical analytic P_i within a few β. The slight oscillation in the P_i value makes some transitory variations in the amount of traffic as shown in Fig.2 at each station within window estimation of stations. Notice also when the P_i value fluctuate, they do so in unison. Also, we assume that P_i value may be updated each β which β have 100sec and estimation window size(η) has 500sec. And an entire simulation time has 5000sec. After the first estimation window period, P_i value is updated as monitoring the traffic of each station.

In Fig.3, like previous result, it shows the adaptive P_i characteristics according to the network throughput which is assumed by changing traffic load distribution, that is, $\lambda_{1,2,4,5} = 0.1$ and λ_3 is changed from 0.1 to 0.5 at time 1000 and from 0.5 to 0.1 at time

3000. The adaptation ability of system for changing arrival rates is of primary importance. Fig.3 shows how the stations cope with a change in traffic by adjusting their P_i based upon the packets they have seen. Comparison to the ideal P_i value for the given traffic pattern show that the system adapts readily to the traffic changes and the method is very effective. Between times 1000 and 3000, stations 1, 2 and 4 reduce their P_i to adjust the increased traffic station 3. After times 3000, all of the stations go back their original P_i, since the traffic rates have returned to their original values. That is, owing to the lower probability P_i of other stations except station 3, it should be maintained the fairness of network.

In Fig.4, we show the effect of sudden addition to a large number of data packets to the queue at one of the stations. In this simulation, 200 extra data packets are inserted into the station 2 at time 1000, after the P_i has settled to the values corresponding to the arrival rates of station. As the result, we may know that stations 1, 3 and 4 lower their P_i to compensate for the added traffic from station 2 until the extra data packets have been cleared at time which the system returns to normal.

In Fig.5, we show the effect window size for each $\eta = 1000$. By default, the window size η at each station was 500sec for earlier simulation. The P_i profiles are much smoother now, reflecting the fact that the stations are performing their estimation over a large sample of the channel traffic. It also takes longer for the stations to readjust their P_i to compensate for any traffic changes but they stay quite close to the proper levels once the latter have been reached.

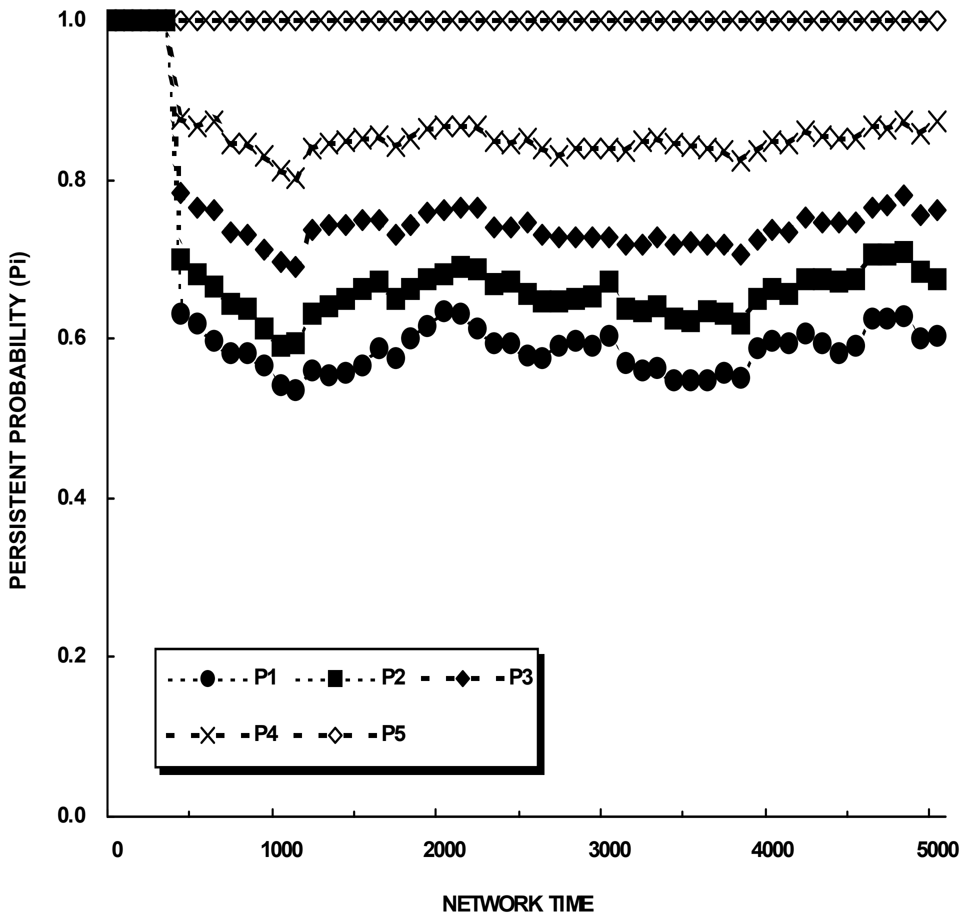

Fig.2 Settling network time of P_i value under CSMA-CD/U/P Protocol with number of station($M=5$) and arrival rates($\lambda_{1,2,3,4,5} = 0.1$)

($\lambda_{1,2,3,4,5} = 0.1$, $\eta=500$ sec, $\beta=100$ sec, $M=5$)

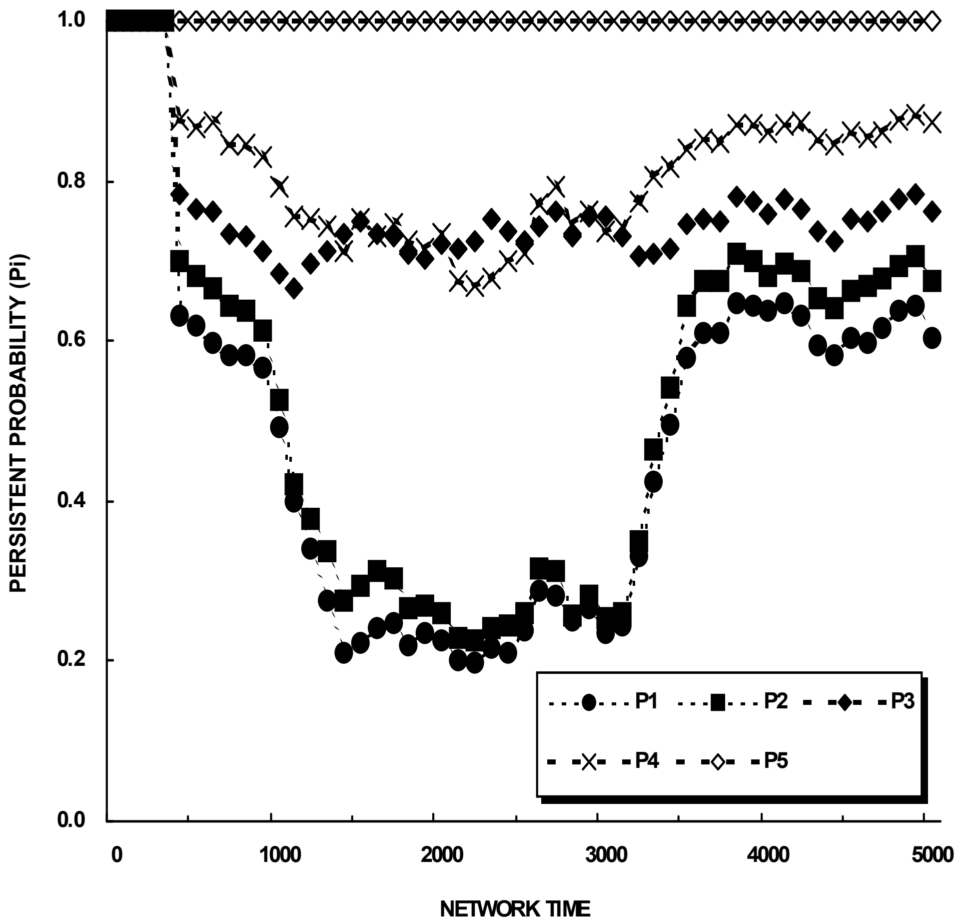

Fig.3 Settling network time of P_i value under CSMA-CD/U/P Protocol with number of station($M=5$) and arrival rates($\lambda_{1,2,4,5} = 0.1$, $\lambda_3=0.5$)

($\lambda_{1,2,4,5} = 0.1$, $\lambda_3=0.5$, $\eta=500$ sec, $\beta=100$ sec, $M=5$)

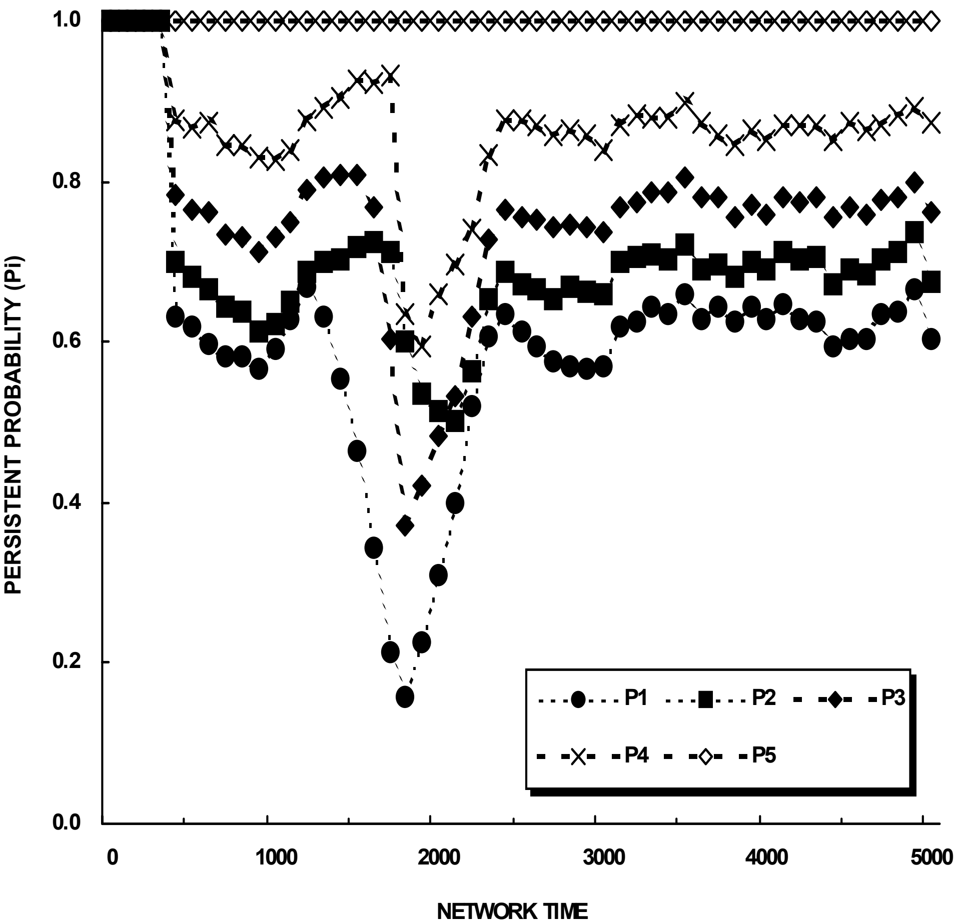

Fig.4 Effect of injecting 200 extra packets under CSMA-CD/U/P Protocol with 200 extra packets of station 2 and arrival rates($\lambda_{1,2,3,4,5} = 0.1$)
($\lambda_{1,2,4,5} = 0.1$, $\lambda_3 = 0.5$, $\eta = 500$ sec, $\beta = 100$ sec, $M = 5$)

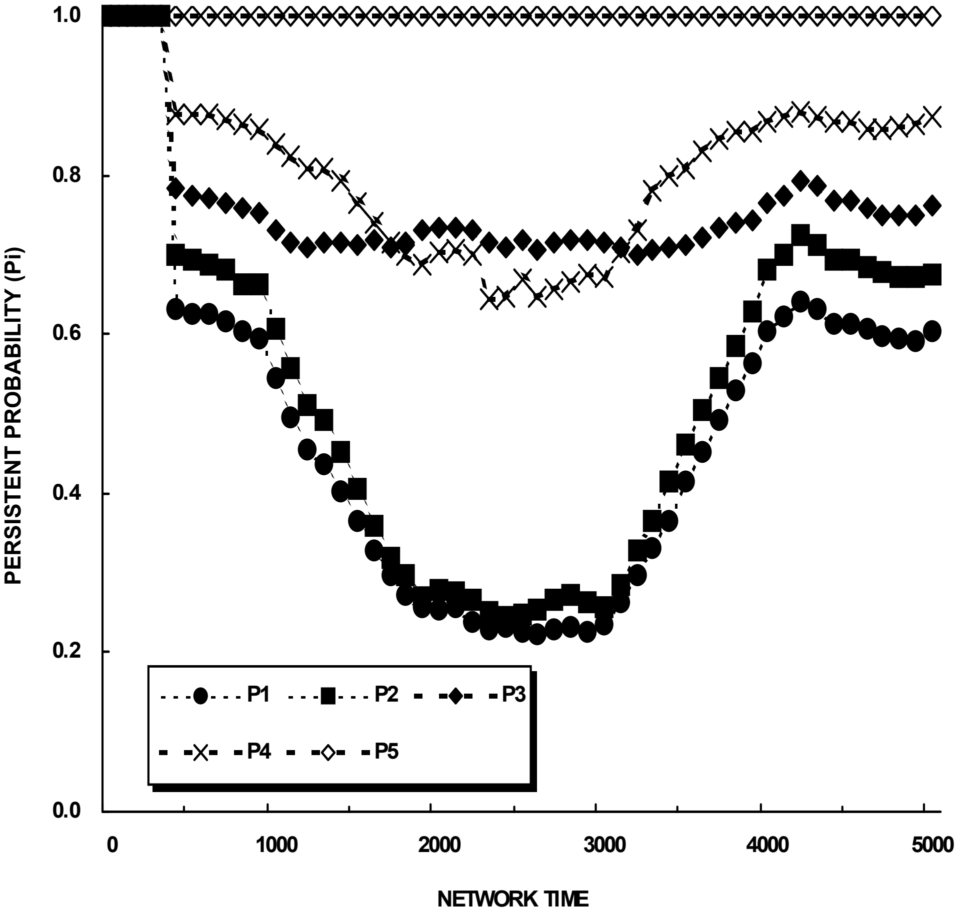

Fig.5 Effect of window size η under CSMA-CD/U/P Protocol with $\eta = 1000$ and arrival rates($\lambda_{1,2,4,5} = 0.1$, $\lambda_3 = 0.5$)

($\lambda_{1,2,4,5} = 0.1$, $\lambda_3 = 0.5$, $\eta = 1000$ sec , $\beta = 100$ sec , $M = 5$)

4. Conclusions

In this paper, we investigated in detail the performance characteristics of the unslotted Pi-persistent CSMA/CD protocol and obtained the dynamic estimation algorithm to get the Pi value. Also, we are performed the various simulation. It is well known that the conventional CSMA/CD protocol, in which bidirectional transmission is done, happens severe degradation in throughput as the normalized propagation delay increases. However, the CATV/LAN network has unidirectional transmission and is employed different collision mechanism. Therefore, we need not to consider the adoption of the CSMA/CD protocol in the random access algorithm considering as the MAC protocol of CATV/LAN network. That is, our analysis has been fully done noting the unidirectional transmission property of the CATV/LAN network which leads to remove the negative effect of propagation delay on the performance of the conventional CSMA/CD protocol. We assume that station of network is composed of a finite number of data stations, M=5 each of which has an infinite storage buffer and arrives at the empty station with data packets of exponential distribution. The simualtion is fulfilled the fixed arrival rate, variable arrival rate, estimation window.

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